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Pasternak et al.

[54] **WIRELESS ATM METROPOLITAN AREA NETWORK**

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[21] Appl. No.: **08/708,593**

[22] Filed: **Sep. 5, 1996**

[51] **Int. Cl.**^{6} **H04L 12/28**

[52] **U.S. Cl.** **370/328**; 370/338; 370/395

[58] **Field of Search** 370/328, 337, 370/338, 347, 348, 349, 395

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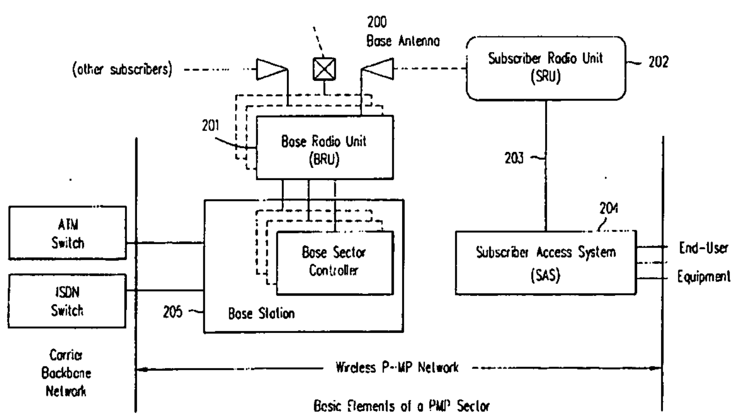
Primary Examiner—Melvin Marcelo
Attorney, Agent, or Firm—Skjerven, Morrill, MacPherson, Franklin and Friel; Alan H. MacPherson; Fabio E. Marino

[57] **ABSTRACT**

The present invention provides an efficient point-to-multipoint microwave ATM network including a base station (BS) broadcasting a continuous transmission with a sector antenna. The system uses time division multiplex (TDM) for downstream transmission and time division multiple access (TDMA) for upstream transmission. The downstream transmission consists of ATM cells encapsulated in MAC protocol data units (PDUs) for forward error correction (FEC) and synchronization. Small Subscriber Terminals (STs), including Subscriber Radio Units (SRUs), receive the broadcast and pass it to a Subscriber Access System (SAS) that drops the ATM cells addressed only to them. To allow strong FEC protection and to maintain the same symbol rate as the downstream transmission without sacrificing bandwidth, a modified trellis code modulation technique, which incorporates Reed Solomon coding, is used during upstream transmission.

13 Claims, 22 Drawing Sheets



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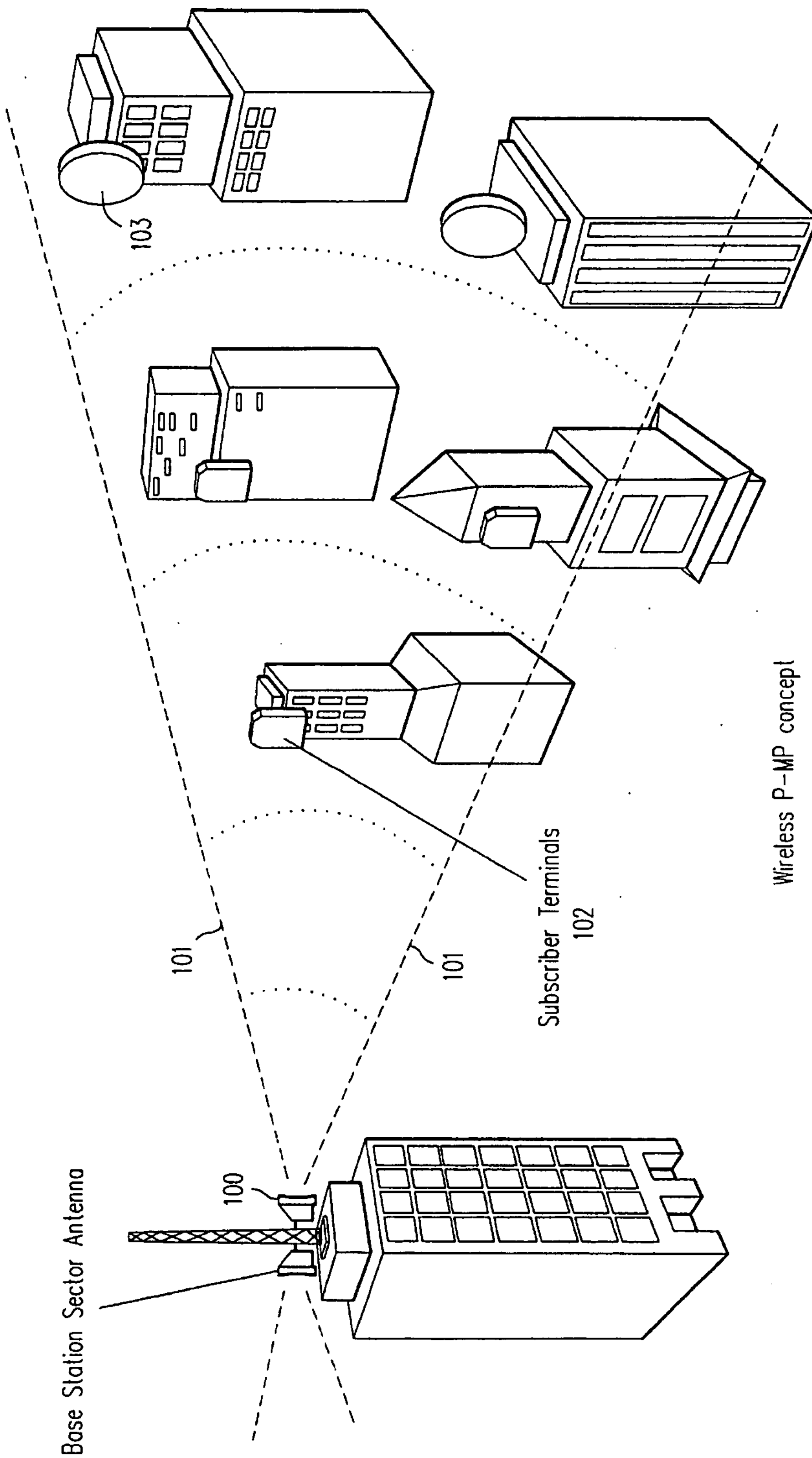
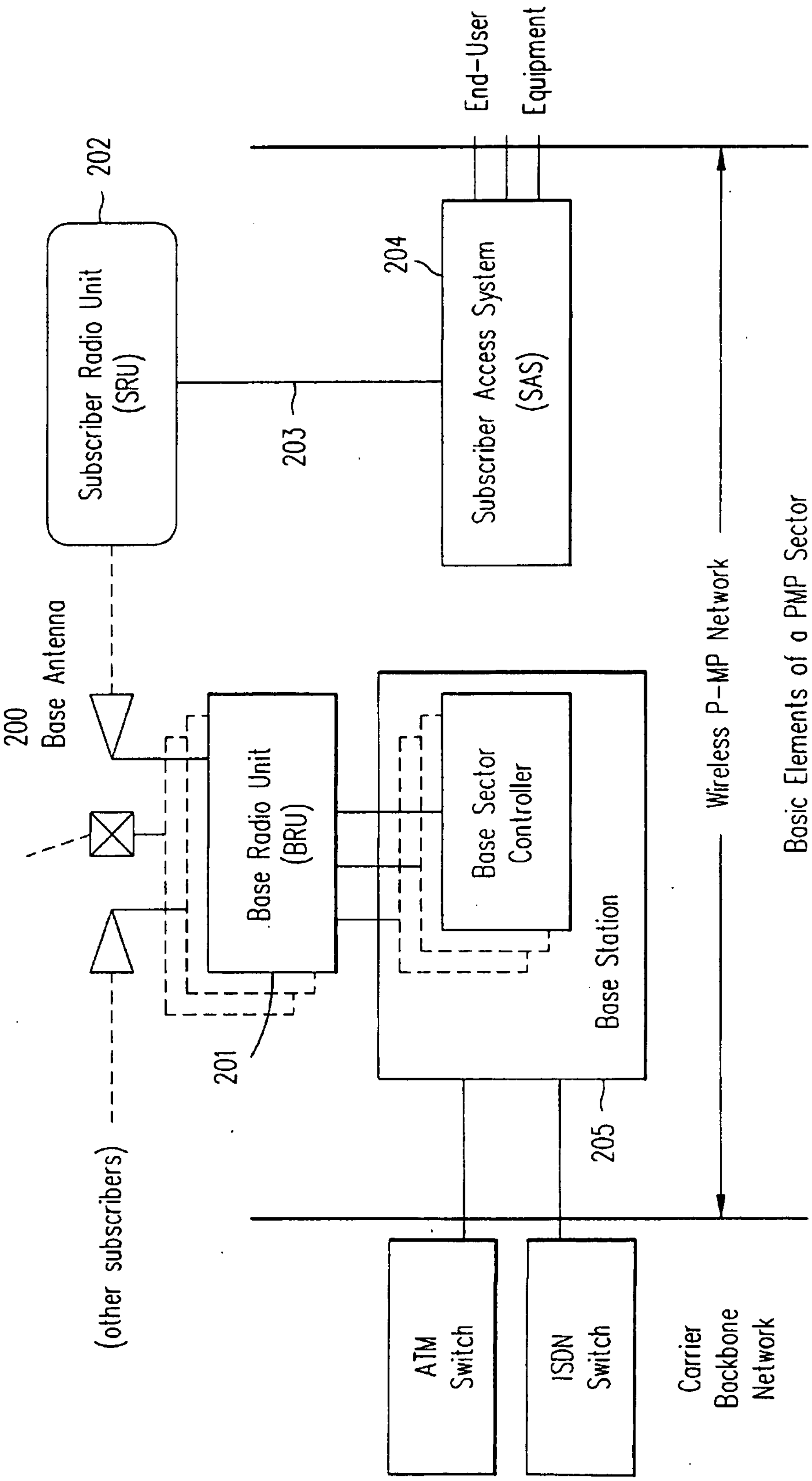


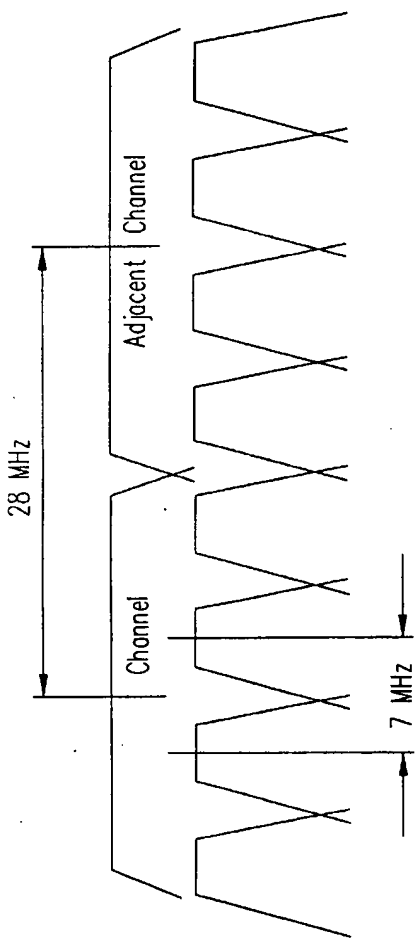
Wireless P-MP concept

FIG. 1

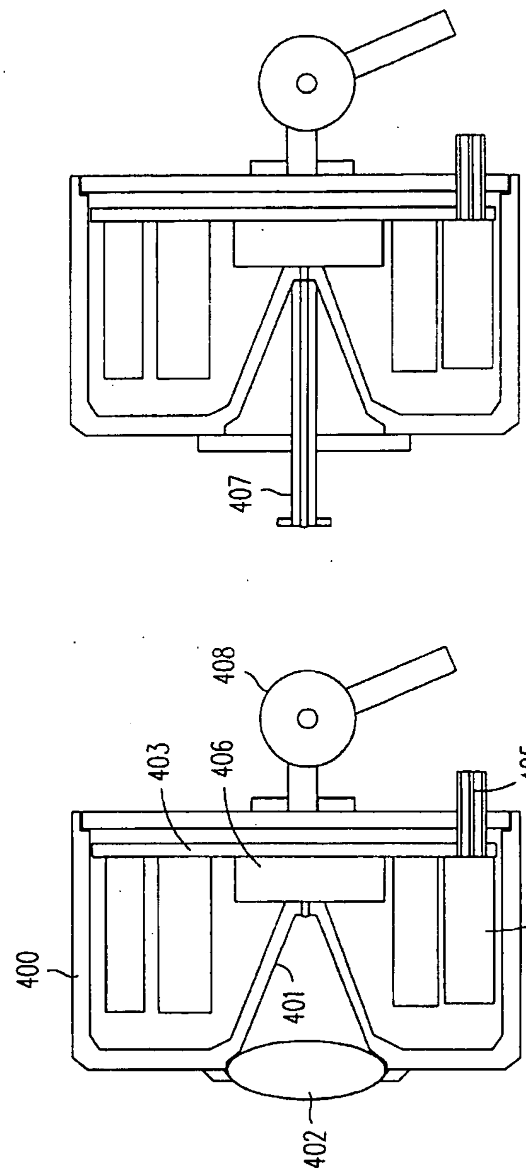


Basic Elements of a PMP Sector

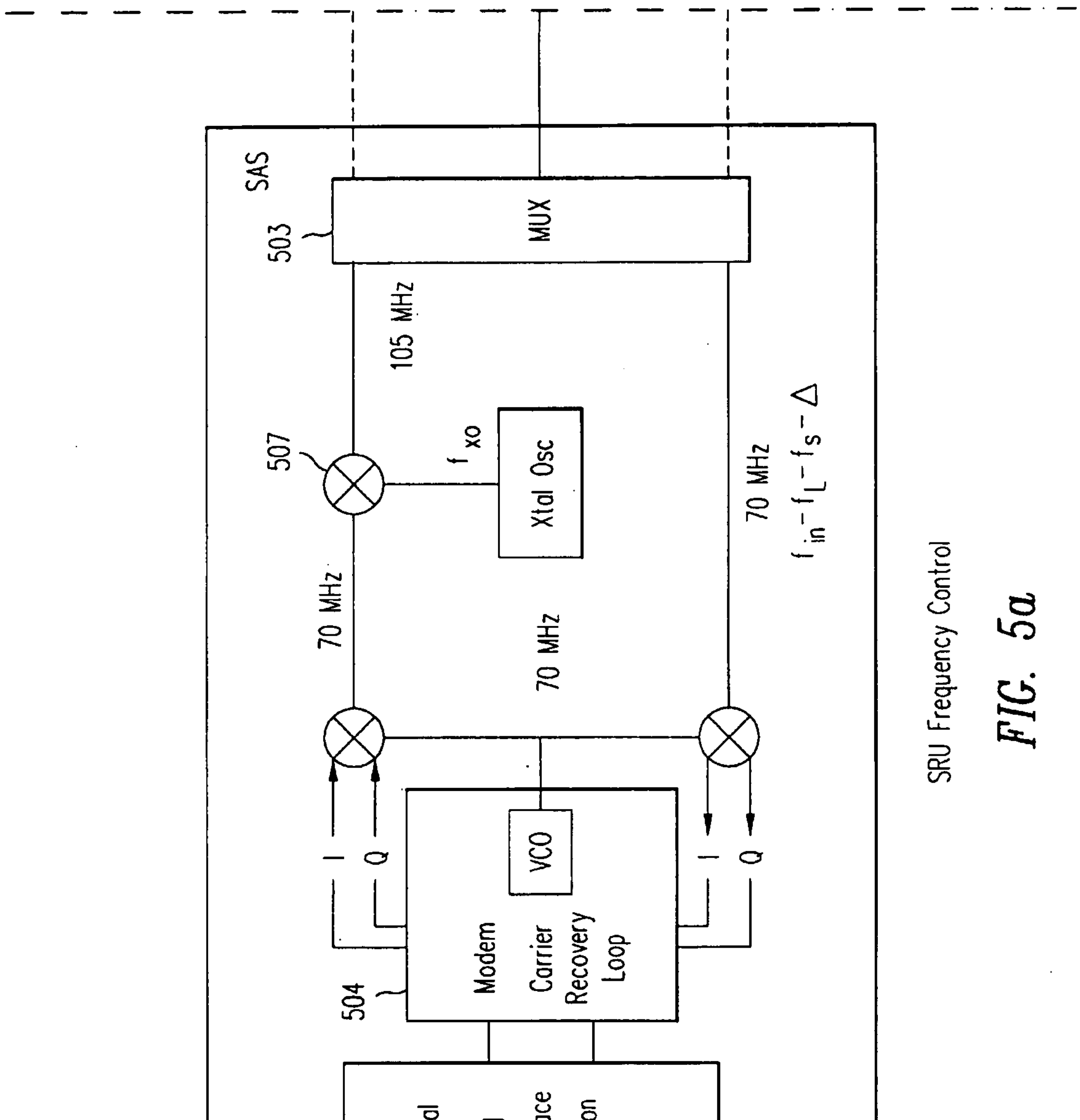
FIG. 2



FDM Structure
FIG. 3

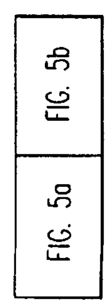


SRU Cross Section
FIG. 4



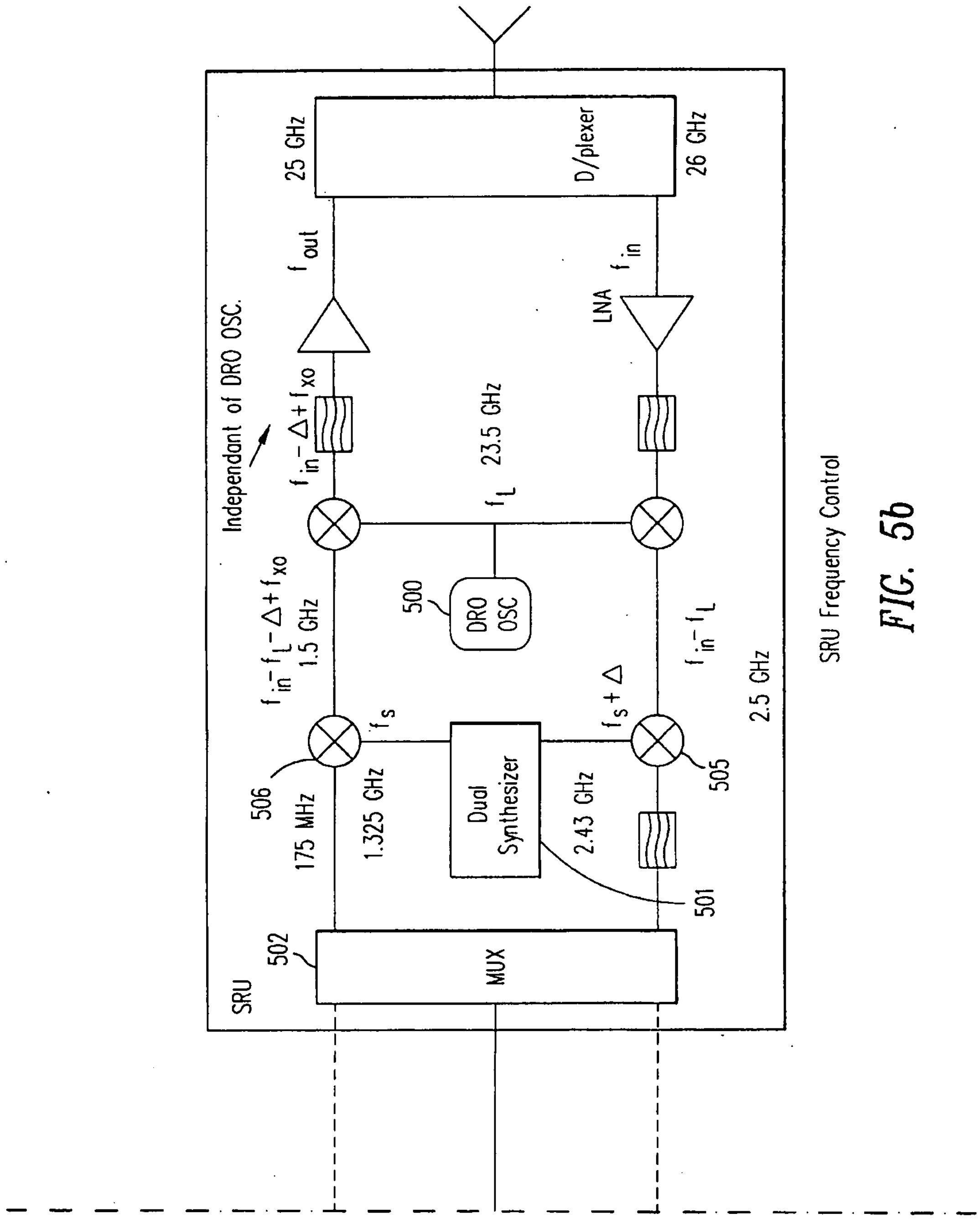
SRU Frequency Control

FIG. 5a



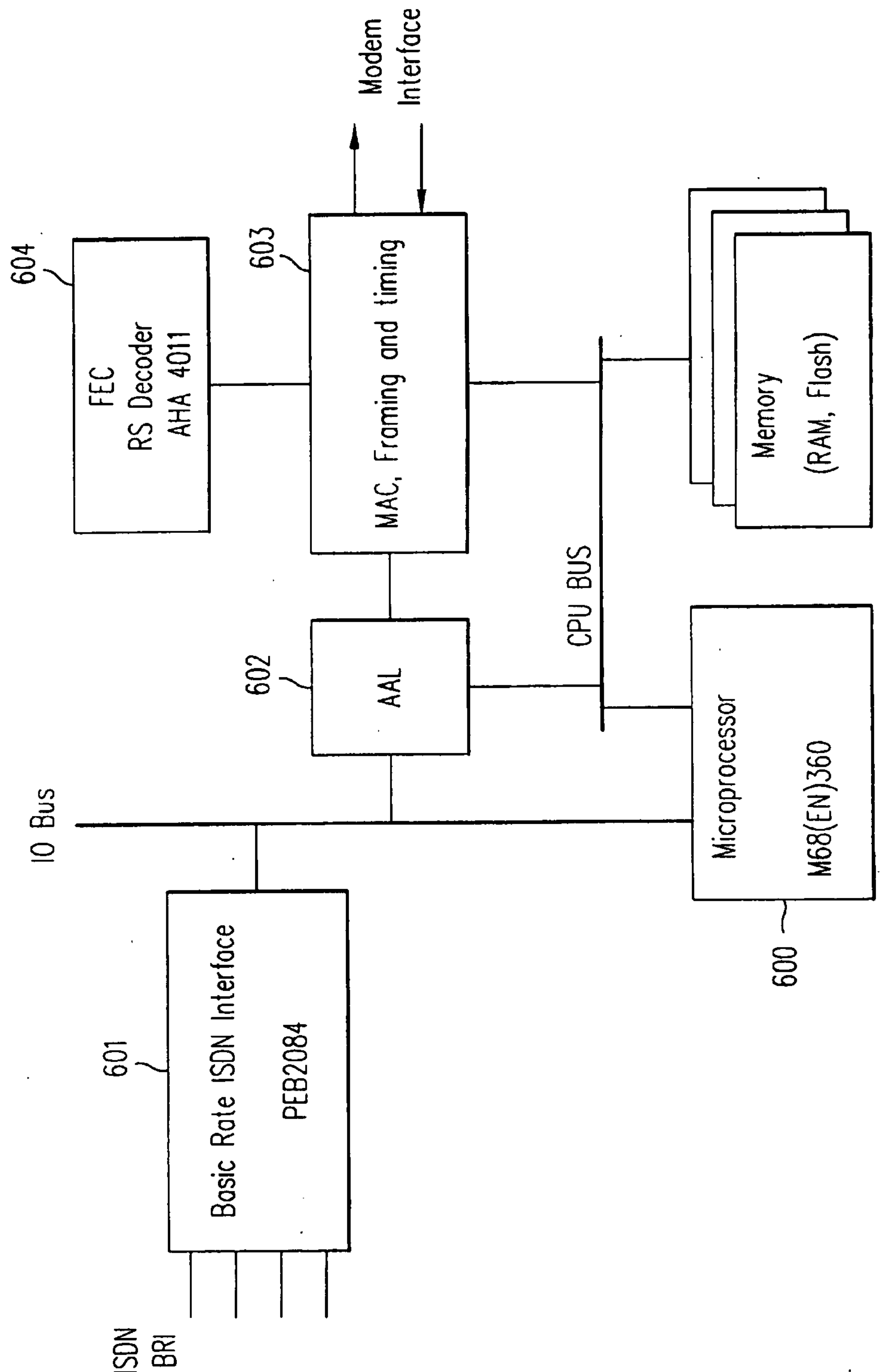
Key to

FIG. 5



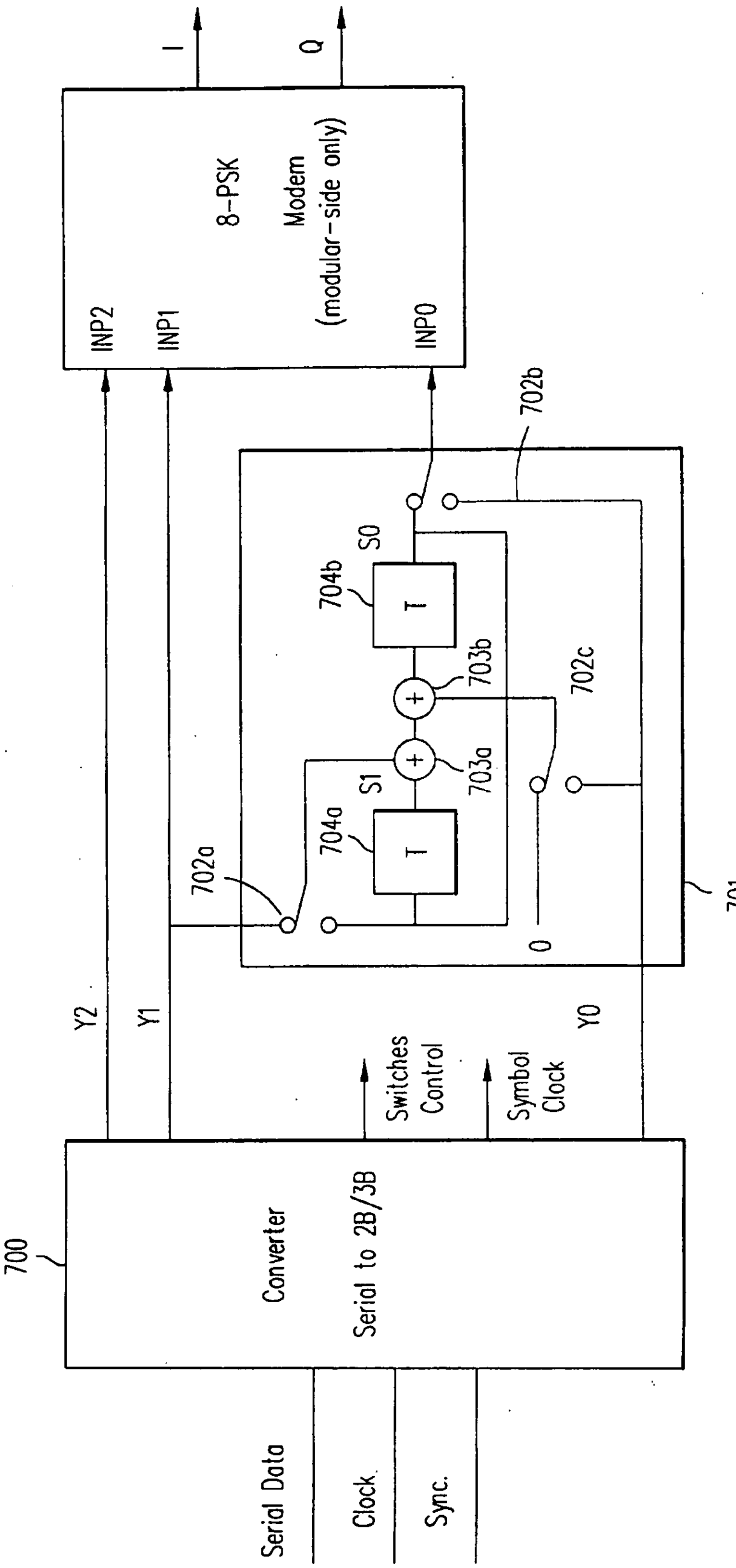
SRU Frequency Control

FIG. 5b



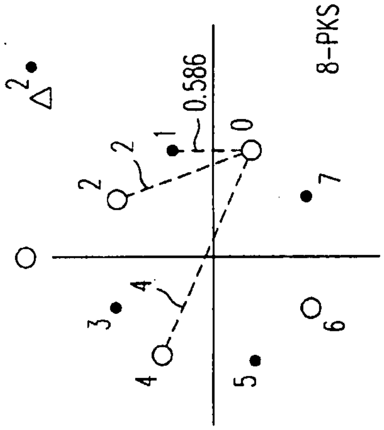
N-ISDN Interface Digital Section

FIG. 6



Modem encoding circuit

FIG. 7



8-PKS Constellation Diagram

FIG. 8

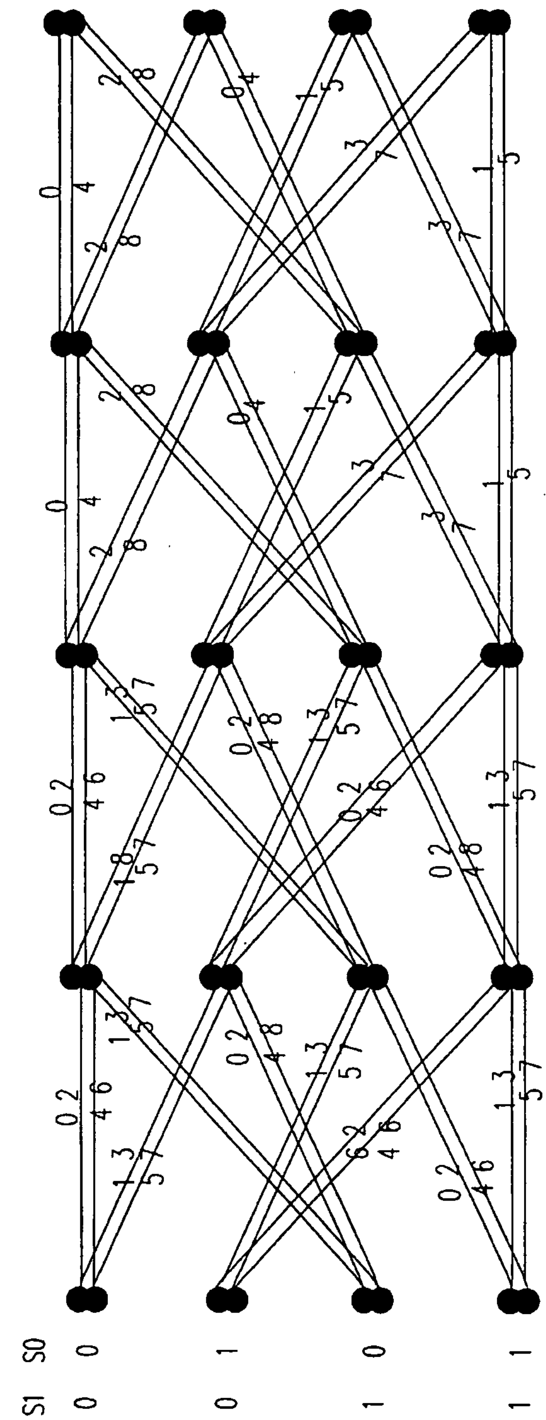
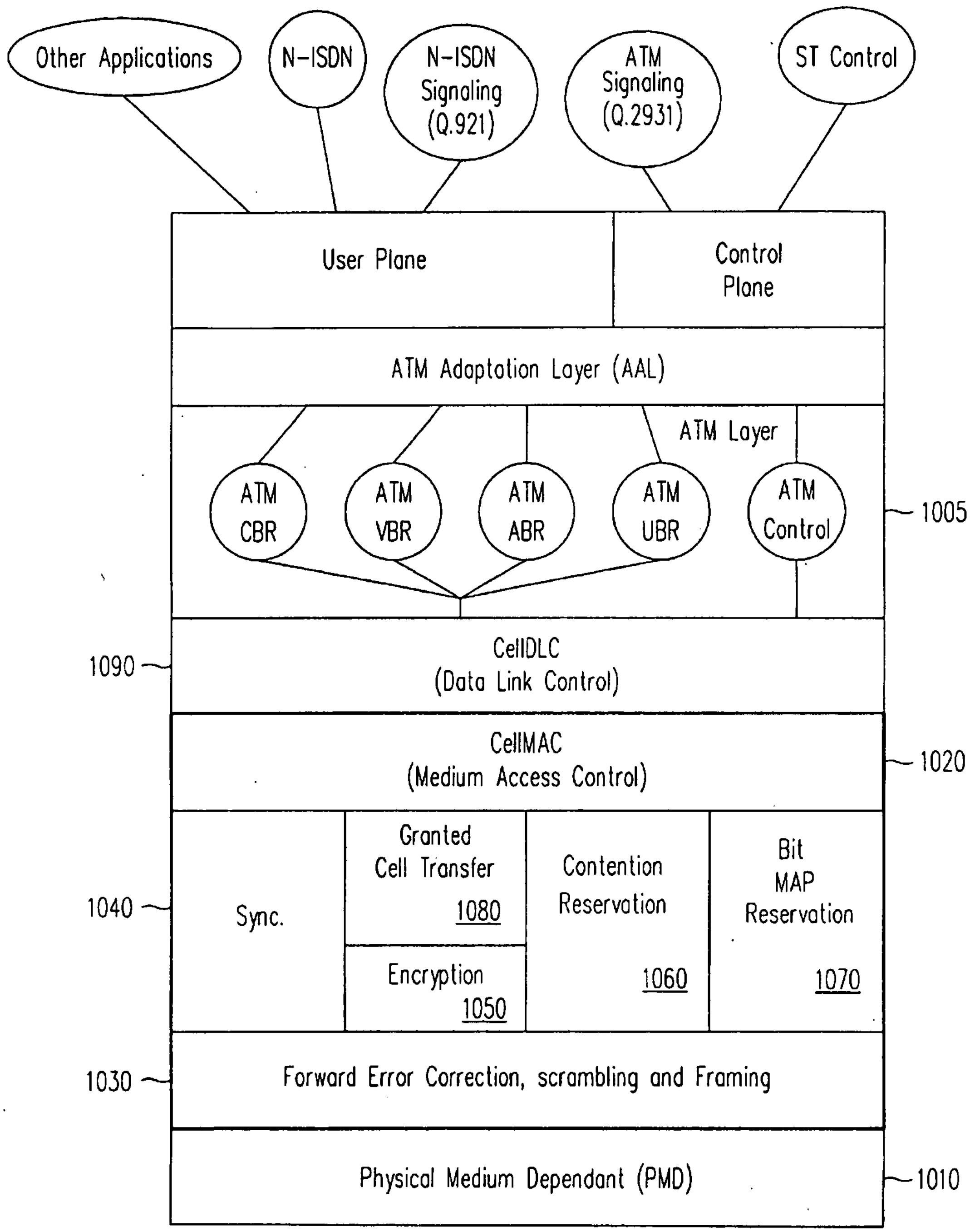
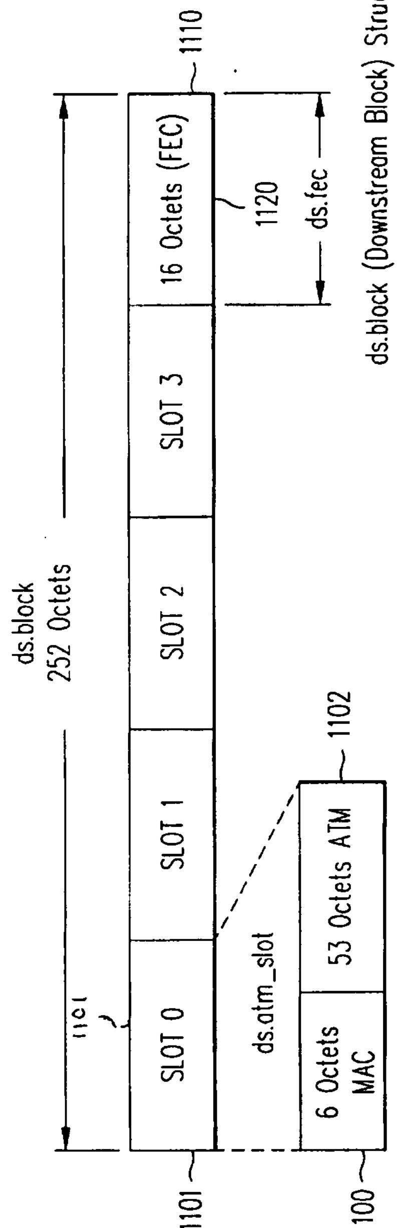


FIG. 9 Modem encoder Trellis diagram



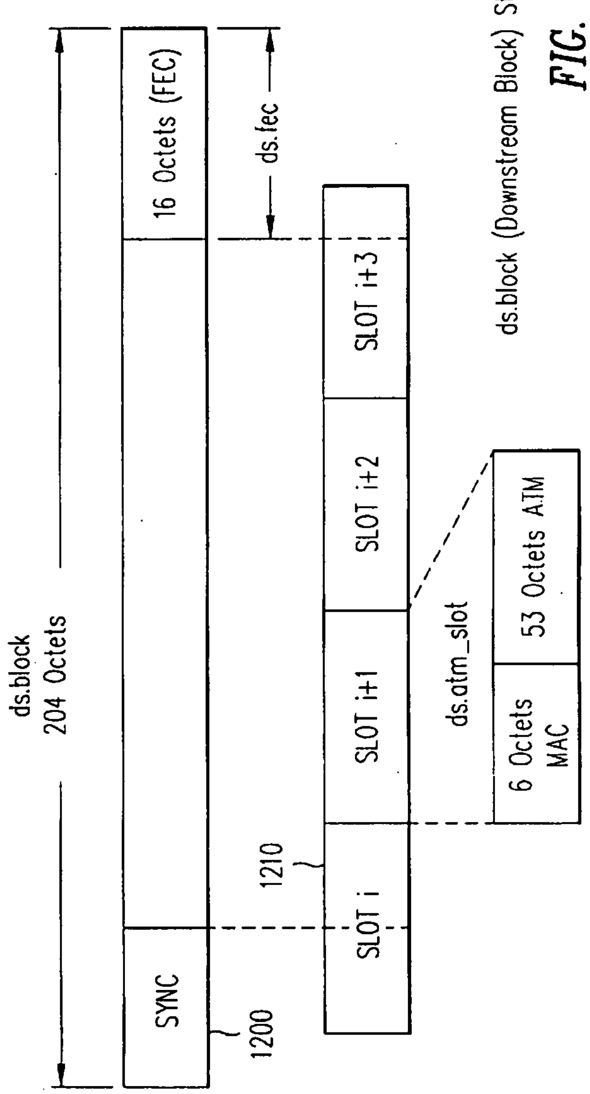
Wireless Air Interface Reference Model

FIG. 10



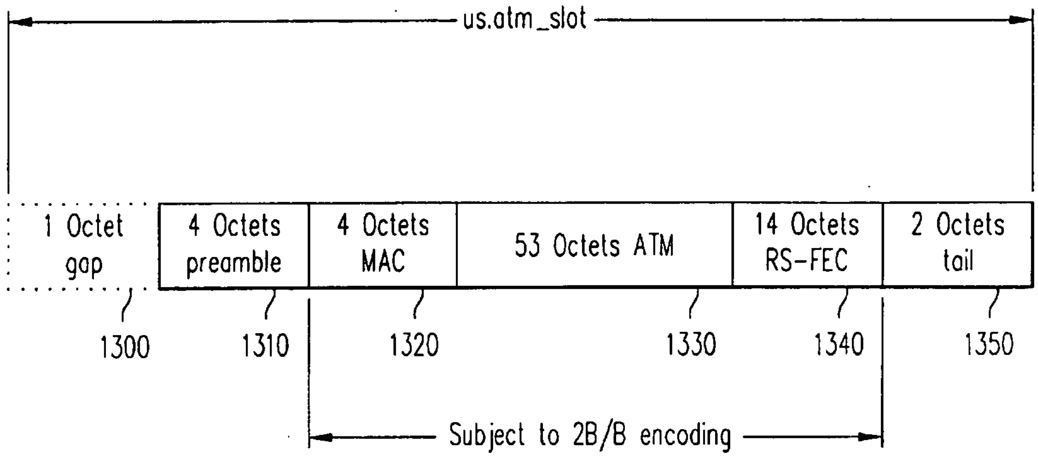
ds.block (Downstream Block) Structure

FIG. 11



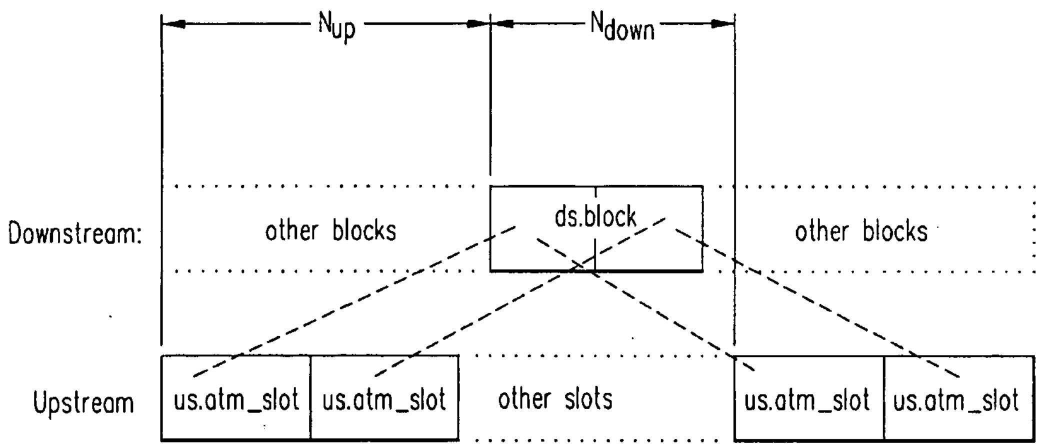
ds.block (Downstream Block) Structure - floating option

FIG. 12



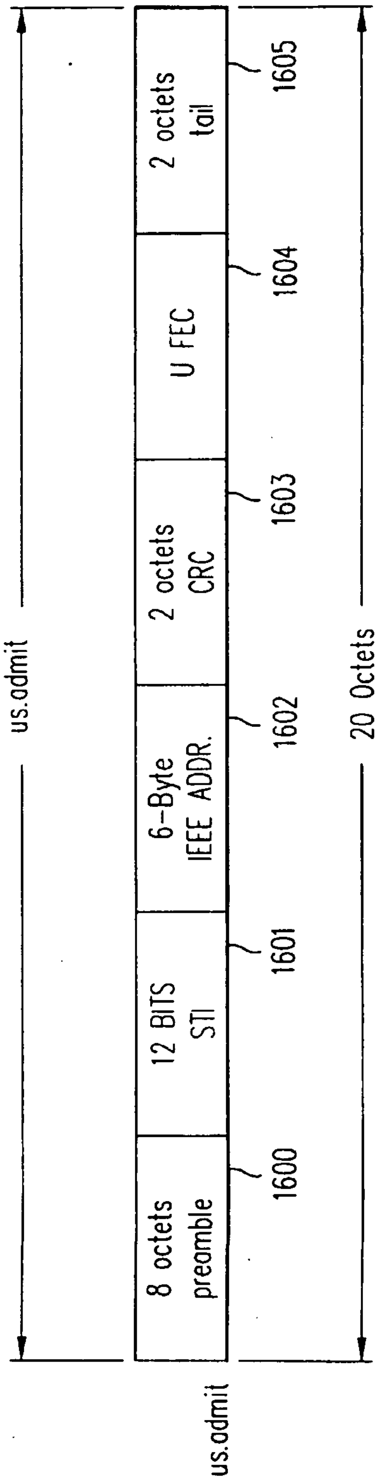
us.atm_slot Structure

FIG. 13



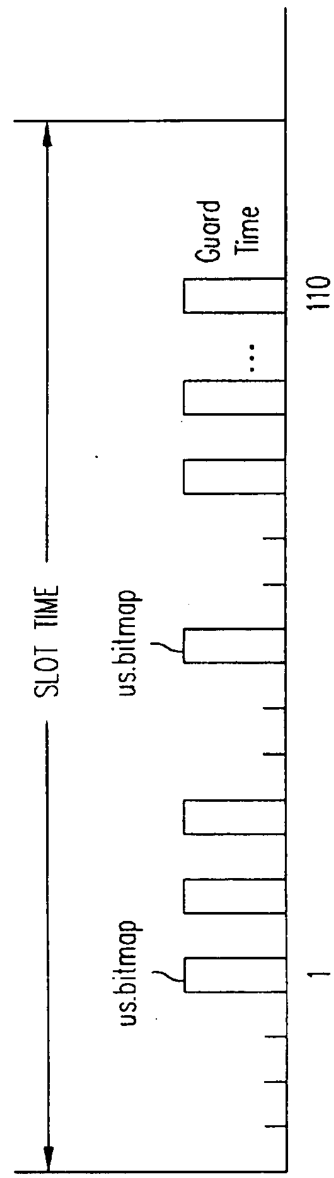
MAC timing relationship

FIG. 14



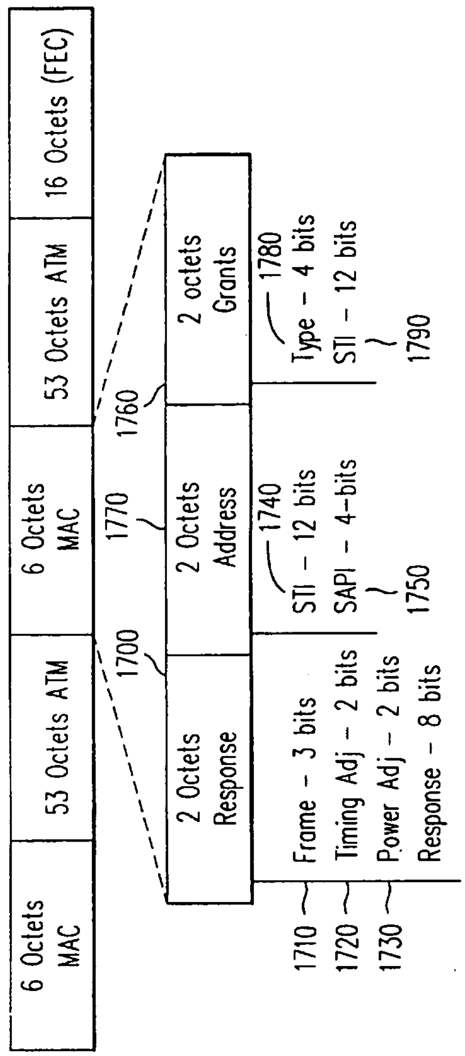
Admission request format

FIG. 16



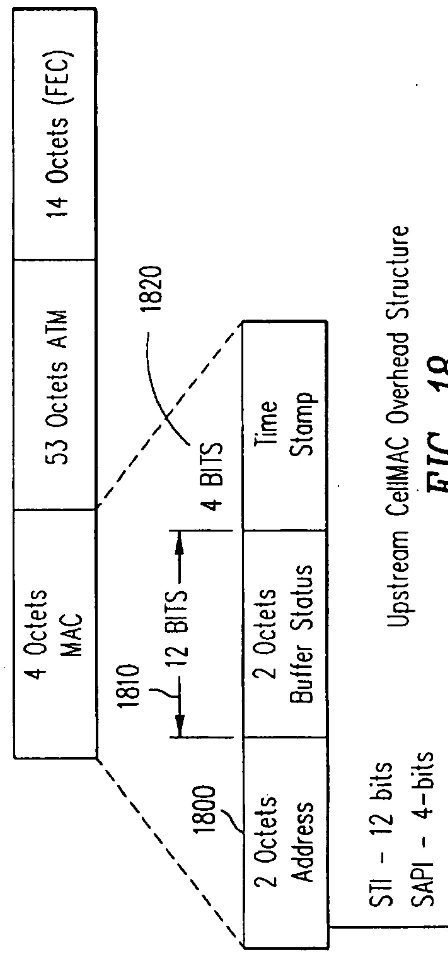
Bitmap Slot Structure

FIG. 15



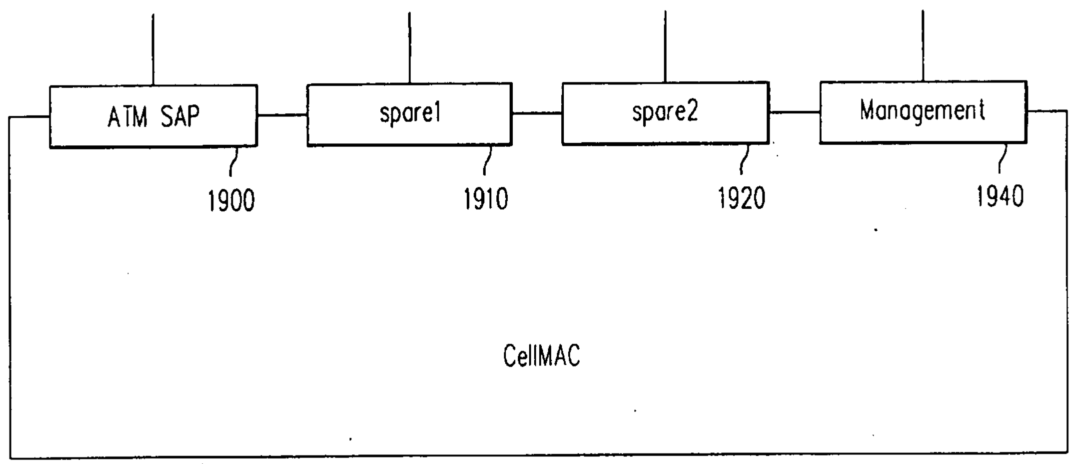
Downstream CellMAC Overhead Structure

FIG. 17



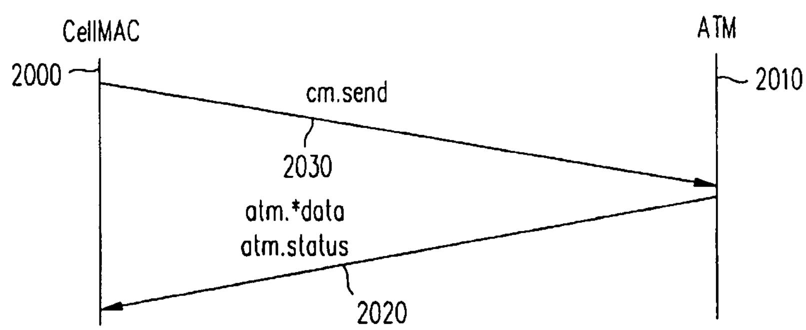
Upstream CellMAC Overhead Structure

FIG. 18



The CellMAC SAPs model

FIG. 19



ATM cell transmission requested by CellMAC

FIG. 20

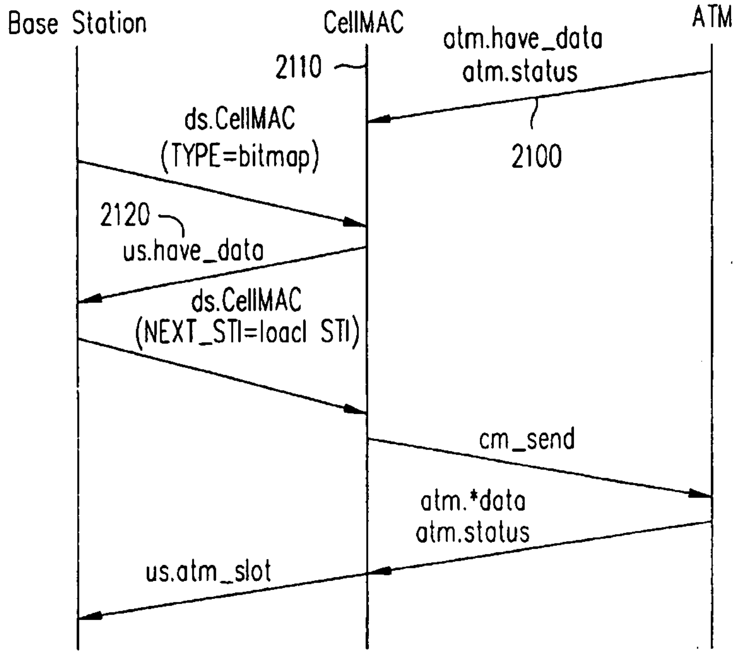


FIG. 21 ATM cell transmission requested by ATM layer - bitmap available

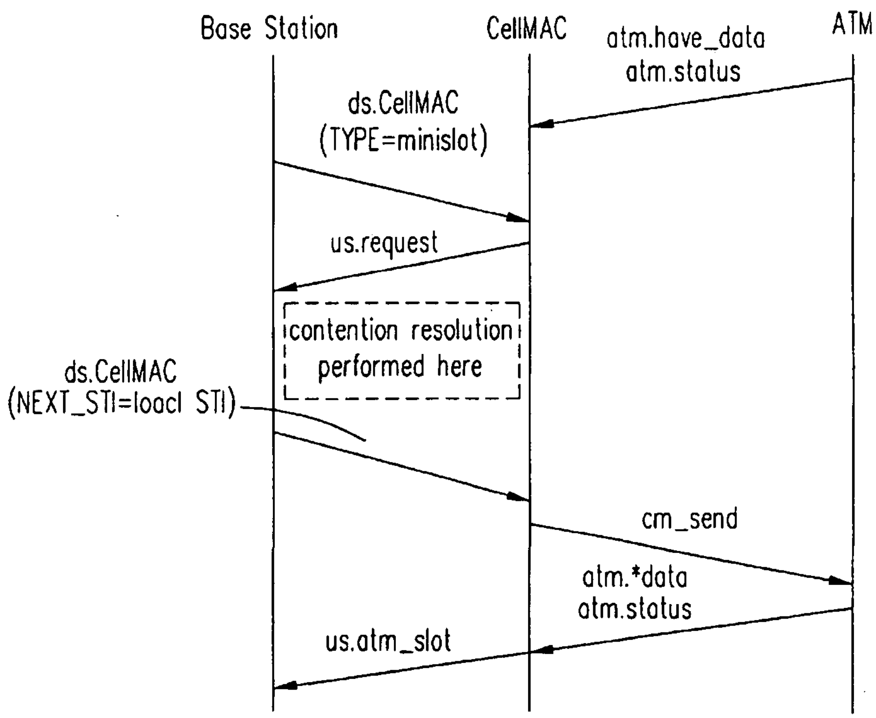
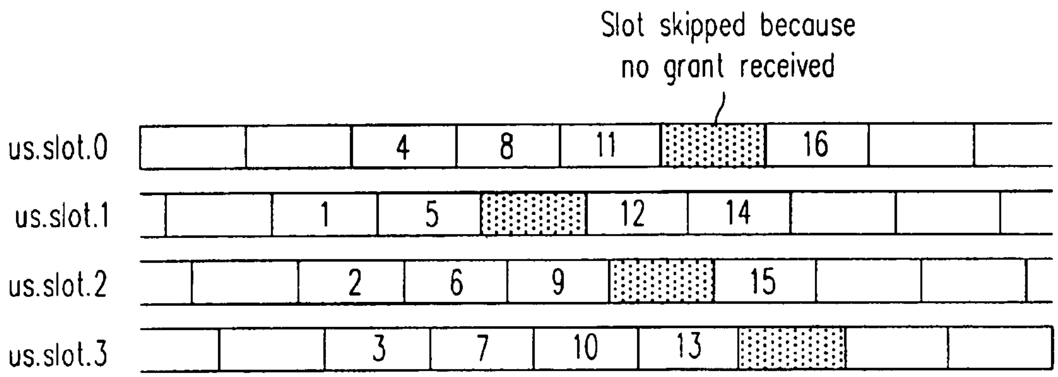
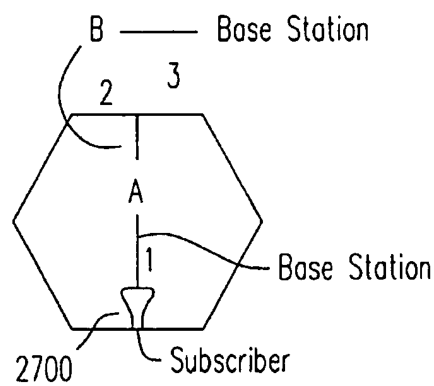


FIG. 22 ATM cell transmission requested by ATM layer by a minislot contention



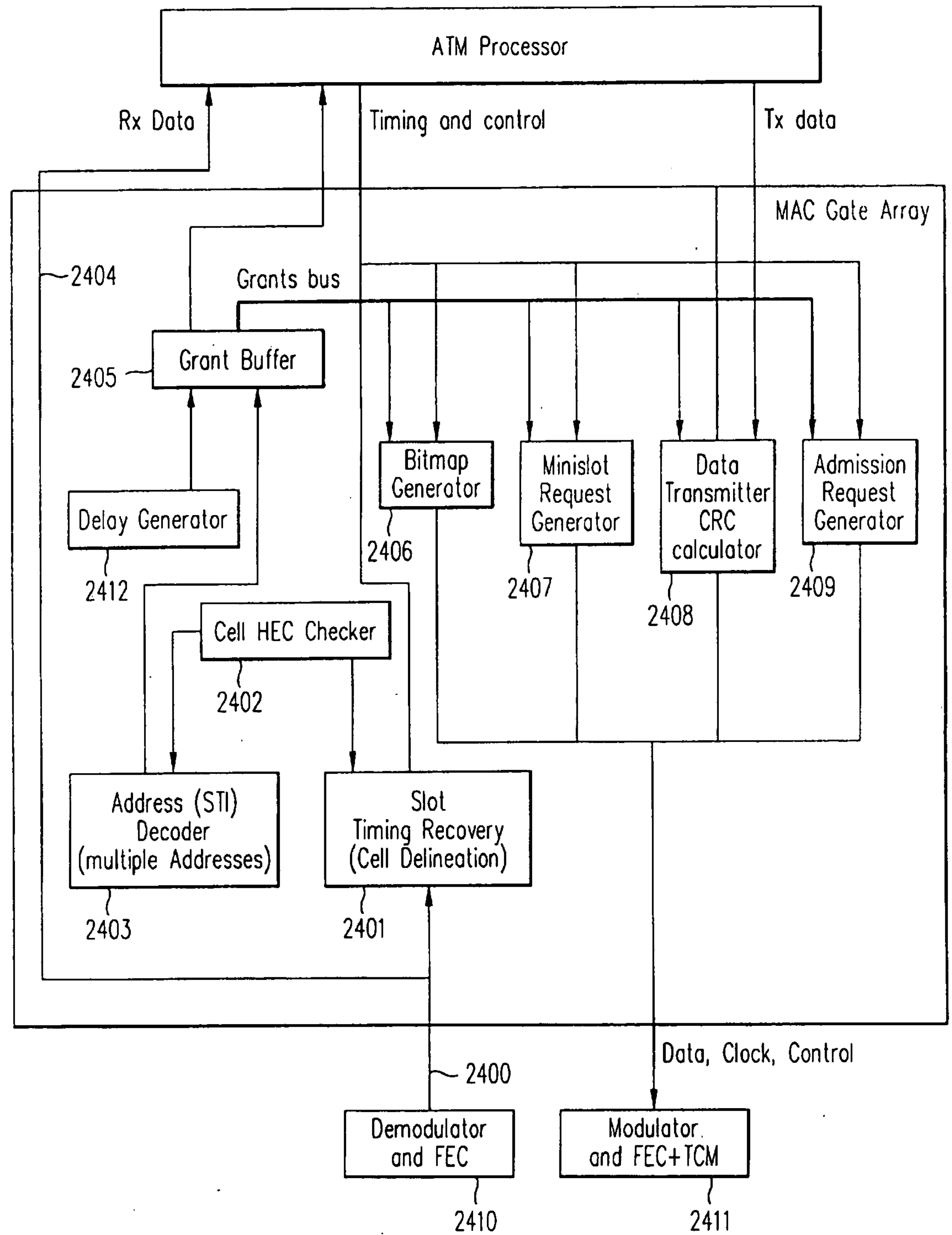
Parallel Cell Transfer

FIG. 23



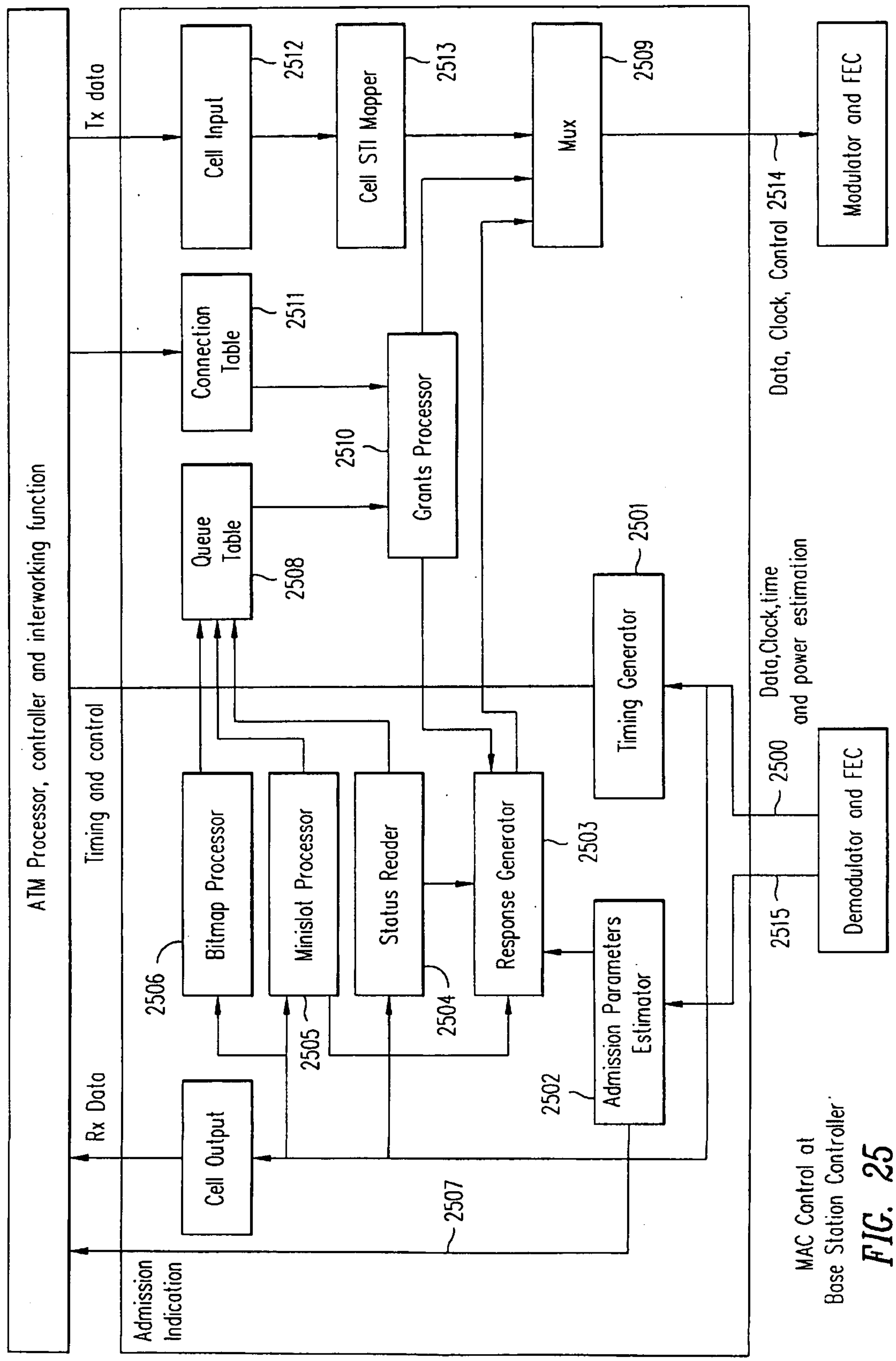
Roll-off interference

FIG. 27



MAC Gate Array Block Diagram

FIG. 24



MAC Control at Base Station Controller

FIG. 25

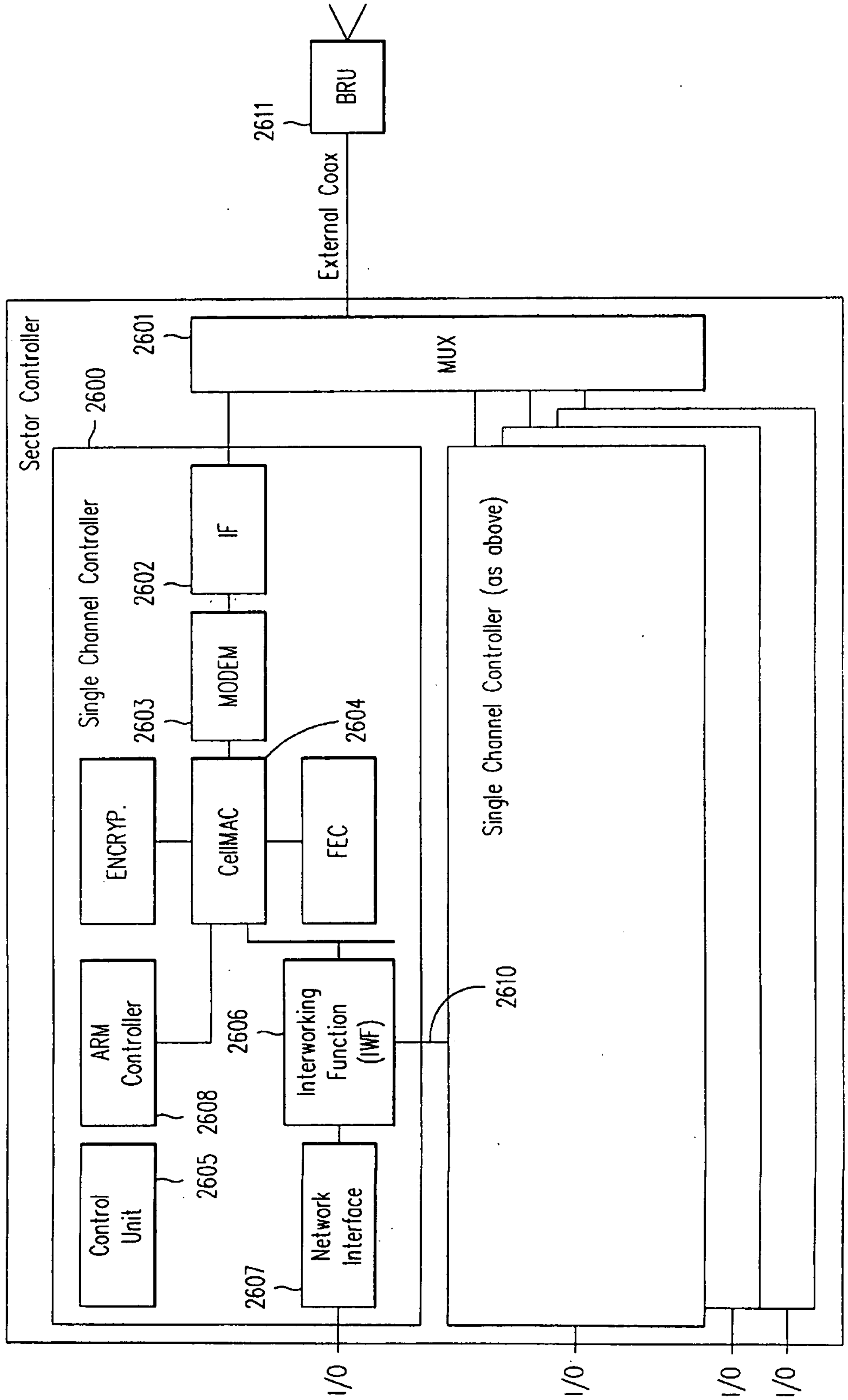
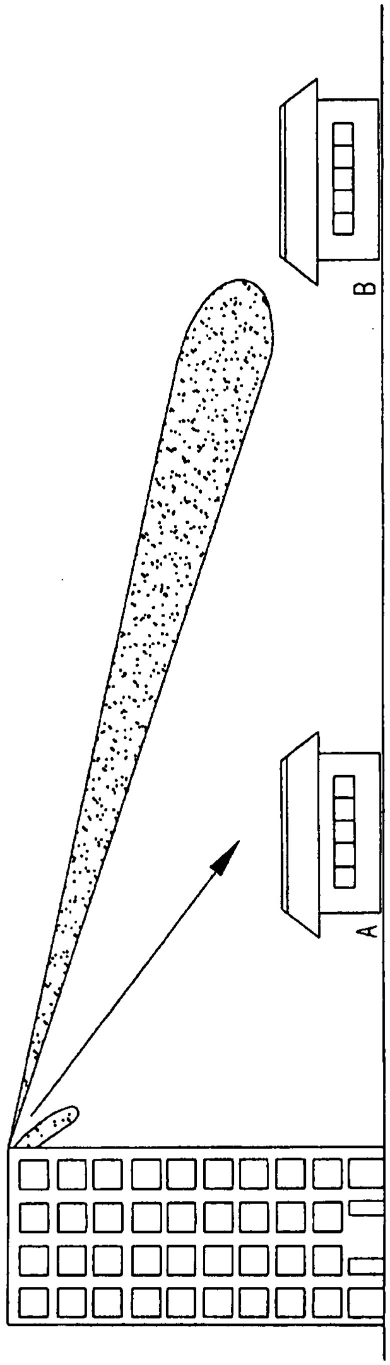
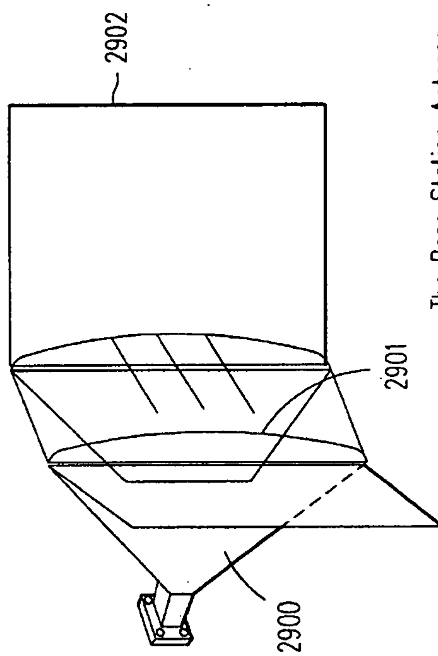


FIG. 26 Base Station Controller Block Diagram



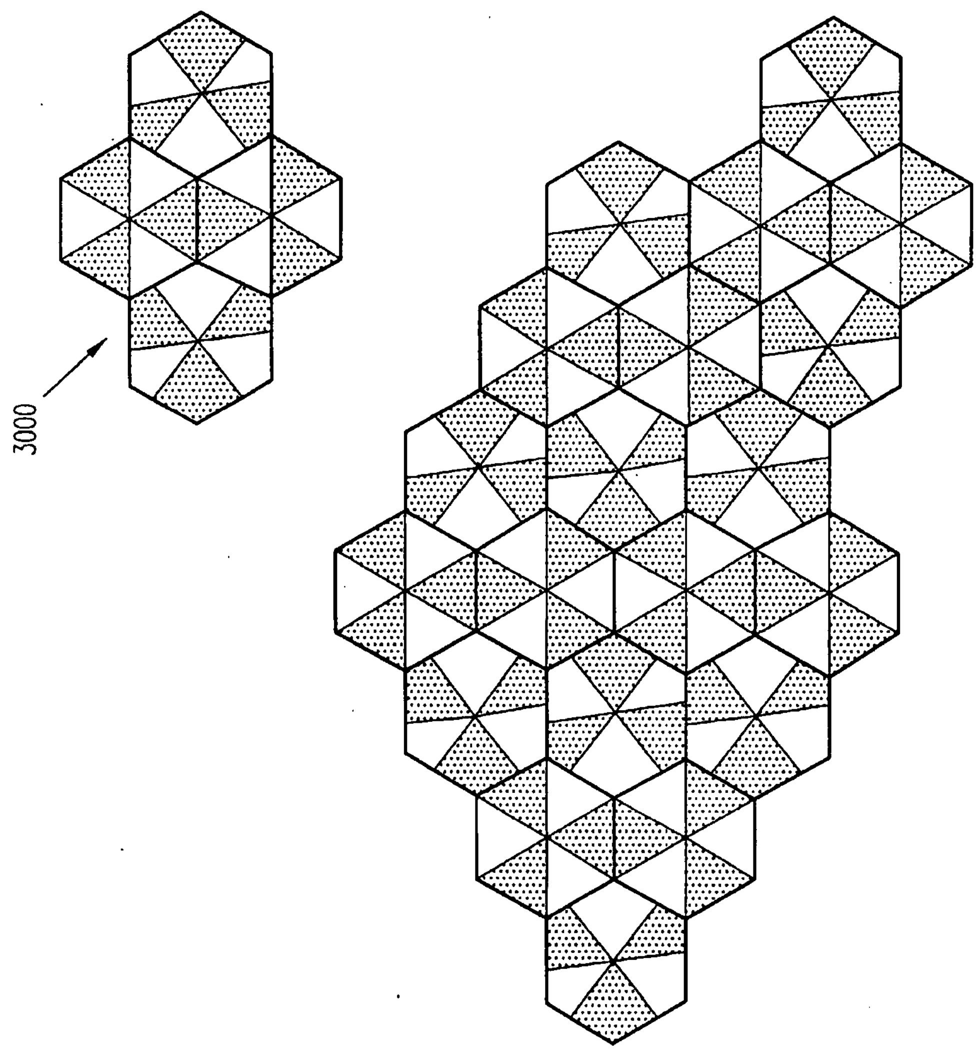
Vertical radiation pattern effects

FIG. 28



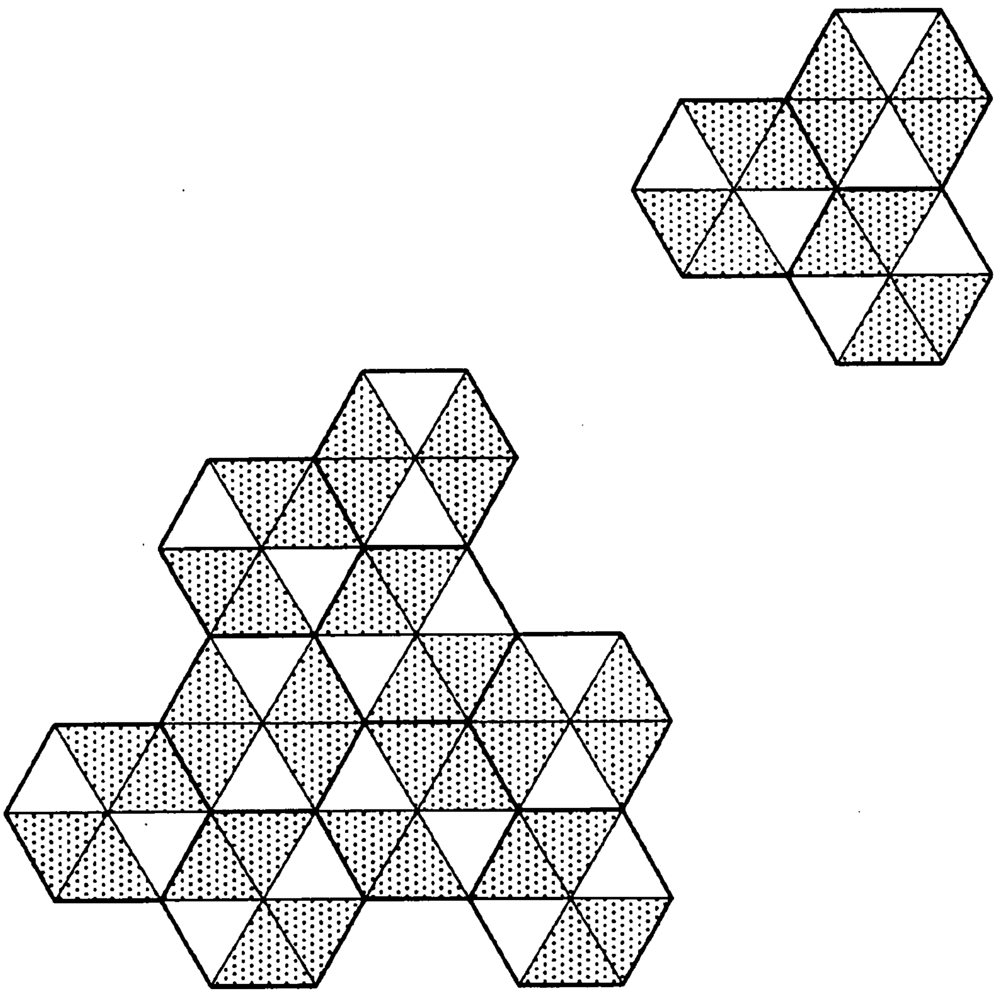
The Base Station Antenna

FIG. 29



Coverage Map with one pair of frequencies

FIG. 30



Symmetrical cellular arrangement with three transmitting channels

FIG. 31

WIRELESS ATM METROPOLITAN AREA NETWORK

FIELD OF THE INVENTION

This invention relates to the field of telecommunication networks and packet switching and, in particular, to providing radio-based point-to-multipoint for cell-switched networks.

BACKGROUND

The Asynchronous Transfer Mode (ATM) method of transmitting and switching multimedia information is replacing older circuit and packet switching techniques, allowing flexible, fast and cost effective provision of new telecommunications service. Among these services are Internet access, Basic rate ISDN, fractional T1/E1 support of cellular PCN network and LAN traffic routing.

These services require expensive infrastructure of transmission facilities, such as copper lines, fiber optics, cable TV or hybrid fiber-coax (HFC). In a competitive environment in which some new telecommunication service providers own some or none of the above facilities, wireless is the other alternative for timely and cost effective deployment of transmission networks. Two previous patent applications (application Ser. No. 08/388,110 filed Feb. 13, 1995 now U.S. Pat. No. 5,648,969 and application Ser. No. 08/538,327 filed Oct. 3, 1995 now U.S. Pat. No. 5,710,756 both assigned to the same assignee and both incorporated herein by reference in their entirety) disclose the structure of reliable networks based on point-to-point radio links. These links allow reliable transmission of ATM traffic with minimum link errors and ATM cell misinsertion. These links are cost effective for high bandwidth and continuous transmission. However, these systems make bad use of equipment and spectrum for applications of intermittent nature such as telephone calls over a wireless link. When a telephone is on hook, the spectrum should be freed for other potential users, and so should the central office transceiver that served that telephone. Data traffic does not always follow the behavior of voice calls. Data may flow slowly, requiring low baud rate for transmission, followed suddenly by a burst of high speed traffic. For efficient use of spectrum, it is desired to allocate bandwidth on demand in a fast and efficient way to handle such bursty information.

These requirements can be served by a multiple access network that uses ATM cells to emulate the variety of services, and by the use of a media access control (MAC) protocol to arbitrate the transfer of data over the air.

ATM services include Constant Bit Rate (CBR), suitable for telephony and video, Variable Bit Rate (VBR), suitable for video applications with variable compression, Available Bit Rate (ABR) suitable for data transactions, and Unspecified Bit Rate (UBR), suitable for e-mail or other non-delay sensitive applications. A MAC layer must support efficiently all of these services.

Due to the high bandwidth required for serving many customers with varying bit rate requirements, high total bandwidth is required in such links. This bandwidth is available only at high microwave frequencies, usually in the range of 10—40 GHz.

The economy of point-to-multipoint systems favors delegating as many functions as possible to the base station ("point") serving the subscriber terminals ("multi-point"), thus saving the cost of replicating the same function in all terminals.

There is, therefore, a need for a point-to-multipoint wireless metropolitan area network with MAC layer suitable for a variety of ATM services, operating at microwave frequencies and allowing cost-effective subscriber radio terminals.

SUMMARY OF THE INVENTION

This invention provides an efficient point-to-multipoint microwave ATM network (sometimes called a "system"). A base station (BS) broadcasts a continuous transmission with a sector antenna. The system uses time division multiplex (TDM) for downstream transmission (from base to subscribers) and time division multiple access (TDMA) for upstream transmission. Existing TDMA protocols, such as those used in HFC applications, use a periodic frame with time slot numbers to indicate who can transmit. This technique is suitable for telephony applications where each voice call occupies a fixed bandwidth, i.e. a fixed number of slots. This technique suffers a major drawback when used in ATM applications. Some ATM CBR rates have periods which are different from other CBR services, that are non suitable for a TDM frame. With different periods, there may be no common frame period to fit all. Eventually, either ATM cells will have to be dropped when their timings coincide, or the ATM network will not admit connections with such conflicts, resulting in low bandwidth utilization. In accordance with this invention, ATM cell transmissions in the upstream direction are granted on a cell by cell basis. If two upstream cells coincide, one is shifted slightly in time, causing small cell delay variation (CDV) which is preferable to losing that cell. The downstream transmission consists of ATM cells encapsulated in MAC protocol data units (PDUs) and other overhead bits used for forward error correction (FEC) and synchronization. Small Subscriber Terminals (STs), including Subscriber Radio Units (SRUs), receive that broadcast and pass it to a Subscriber Access System (SAS) that drops the ATM cells addressed only to them. Each MAC PDU transmitted by the BS may include a grant for a specific ST. The grant specifies which ST is allowed to transmit but not which time slot. The time slot of transmission is implicit in that the time slot is simply a fixed number of time slots from the grant reception event.

The upstream transmission includes single ATM cells with their MAC and physical layer overhead. To allow strong FEC protection and to maintain the same symbol rate as the downstream transmission without sacrificing bandwidth, a modified trellis code modulation technique is used. Trellis code modulation includes transmission of redundant code bits for error correction. In accordance with this invention, the trellis code rate is increased, causing it to weaken its noise immunity, i.e. more bits are excluded from the trellis code overhead. For example, the code rate is increased to 5/6 from 2/3, meaning 5 out of 6 bits are data and only one out of 6 is trellis code overhead. However this weakening is more than compensated for by using the extra bits for Reed Solomon coding. The combined concatenated code has better noise immunity then a TCM code alone (at a lower code rate), yet they both use the same symbol rate and the same payload.

The Subscriber Radio Units (SRUs) are simplified in design by having them phase locked to the Base Station carrier. In accordance with this invention, the transmit signal frequency is phase locked with a frequency offset to the original signal, thus the phase noise remains almost as low as that to the expensive base station microwave synthesizer.

To provide high antenna gain and low cost, an integral lens-horn antenna is used in the SRU. The base station uses

a horn antenna that in accordance with this invention includes adjustable beam width by use of absorption plates and an extended main radiation lobe in the vertical dimension by use of a lens or a geometry with intentional phase plane deviation.

The ATM traffic gathered from the STs is optionally shaped by a cell jitter attenuator to reduce cell delay variation (CDV) occurring over the link. The Base Sector Controller (BSC) includes the master MAC controller and application-specific processing circuits and software. In the case of supporting basic rate ISDN services, the BSC includes an interworking function that converts individual circuits-emulation ATM cells from each ST to a combined emulated T1 or E1 line with embedded signaling according to V5.1 or V5.2 protocols. This signal can then be combined with similar signals from other BSCs, if desired by an external ATM switch. The combined signals travel via the ATM backbone network until they reach a site with an ISDN central office switch. The signals are then transferred by the ATM switch at that site to a physical T1/E1 line that can be connected to the ISDN switch or other equipment.

This invention will be more fully understood in conjunction with the following detailed description taken together with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a wireless point-to-multipoint (P-MP) network of a type suitable for use in a city.

FIG. 2 shows the basic building blocks of a P-MP cell site.

FIG. 3 shows an example of frequency division of the spectrum for transmission in a sector.

FIG. 4 shows a cross section of a Subscriber Radio Unit with a built-in lens-horn antenna and with a waveguide extension option for external antenna connection.

FIG. 5 shows a block diagram of the subscriber terminal with a focus on frequency control.

FIG. 6 shows a block diagram of the digital section of a subscriber access system for a basic rate ISDN application.

FIG. 7 shows a modem trellis code modulation encoder for the upstream transmission.

FIG. 8 is a phasor diagram showing a constellation of 8-PSK modulation.

FIG. 9 is a modem TCM trellis diagram with rate ⅚.

FIG. 10 shows a reference model for the air interface MAC protocol and other protocol layers.

FIG. 11 shows a downstream ds.block MAC primitive.

FIG. 12 shows another embodiment of the ds.block primitive with a floating payload structure.

FIG. 13 shows the upstream primitive us.atm_cell structure.

FIG. 14 shows the timing relationship between the downstream and upstream slot and pointers relationship as viewed from the base station.

FIG. 15 shows the timing concept of bitmap reservation.

FIG. 16 shows the admission request primitive.

FIG. 17 shows the structure of each downstream slot associated with the CellMAC overhead structure.

FIG. 18 shows the upstream primitive MAC overhead structure.

FIG. 19 shows the concept of MAC SAPs.

FIG. 20 shows the handshake between the MAC layer at the subscriber side and the ATM layer.

FIG. 21 shows ATM cell transmission originating from the ATM layer at the subscriber terminal if bitmap reservation is available.

FIG. 22 shows the same transmission as in FIG. 21 but with contention reservation.

FIG. 23 shows the transfer of ATM cells by an ST which is capable of transmitting in four channels.

FIG. 24 shows a block diagram of a base station.

FIG. 25 shows a block diagram of the MAC layer controller at the base station.

FIG. 26 shows a block diagram of a base station controller.

FIG. 27 shows a model of interference from remote base station to a subscriber.

FIG. 28 shows the vertical radiation pattern of an unsuitable antenna.

FIG. 29 shows a suitable base station antenna.

FIG. 30 shows a cellular coverage map with asymmetrical sectors but one pair of frequencies.

FIG. 31 shows a cellular map with three frequencies.

DEFINITION OF ACRONYMS

Note: Netro-specific terms use BOLD ITALIC characters.

AAL ATM Adaptation Layer
ABR Available Bit Rate, an ATM service in which the source rate may change during a connection wherein cell delay variation is not specified.
AGC Automatic Gain Control
ARM Adaptive Radio-Resource Management
ARQ Automatic Retransmit Request
ATM Asynchronous Transfer Mode
BPSK Bipolar Phase Shift Key
BRU Base Station Radio Unit
BS Base Station
BSC Base Station Sector Controller
CBR Constant Bit Rate—an ATM service with guaranteed rate of transport and cell delay variation.
CDV Cell (ATM) Delay Variation
DC Direct Current
DRO Dielectric Resonant Oscillator
DVB Digital Video Broadcast
E1 European digital line interface at 2.048 Mbps.
E2 European digital line interface at 8.448 Mbps.
E3 European digital line interface at 34.368 Mbps.
EPROM Erasable Programmable Read-Only Memory
EEPROM Electrically-Erasable Programmable Read-Only Memory
FDD Frequency Division Duplex
FPGA Field Programmable Gate Array
FEC Forward Error Correction
HEC Header Error Control
HFC Hybrid Fiber Coax
ID Identification
IP Internet Protocol
ISDN Integrated Services Digital Network
LAN Local Area Network
LED Light Emitting Diode
LNA Low Noise Amplifier
MAC Media Access Control
Mbps Mega bits per second
MMIC Monolithic Microwave Integrated Circuit
NMS Network Management System
P-MP Point to multipoint
PBX Private Branch Exchange, a generic term for a voice switch.
PCN Personal Communication Networks—A mobile telephone service type.

PCS Personal Communication Services—A mobile telephone service.
PDU Protocol Data Unit—the payload field of a protocol packet.
PN Pseudo Noise
PSK Phase Shift Keying
PROM Programmable Read-Only Memory
PTT Post Telephone and Telegraph, a common name for government service providers
QPSK Quadrature Phase Shift Keying
RISC Reduced Instruction Set Computer
RS Reed Solomon (a block error correction code)
RU Radio Unit
SAP Service Access Point
SAPI Service Access Point Identifier
SAS Subscriber Access System—the indoor portion of a subscriber terminal
SRU Subscriber Radio Unit
ST Subscriber Terminal (SRU+SAS)
STI Subscriber Terminal Identifier
STM Synchronous Transfer Mode
TBD To be defined (later)
TCM Trellis Code Modulation—an error correction method based on encoding the transition of modulation symbols.
TDD Time Division Duplex—transmission and reception at same frequency alternating in time
TDM Time Division Multiplex
TDMA Time Division Multiple Access
Terminal A system consisting of SAS, SRU and the interconnections.
UBR Unspecified Bit Rate—an ATM service with no guaranteed rate, cell loss ratio or delay.
VBR Variable Bit Rate—an ATM service.
VC Virtual Circuit. In ATM cells is made of VPI/VCI.
VPI/VCI Virtual Path Identifier/Virtual Channel Identifier—an ATM address.
XOR Exclusive OR

DETAILED DESCRIPTION

A sector of a P-MP wireless transmission is shown in FIG. 1. A base station antenna **100** transmits to a sector **101** of 30 to 90 degrees. Subscribers wishing to get telecommunications services have subscriber terminals (STs) installed in their houses or offices. Nearby subscribers may install small outdoor radio units (SRUs)**102**. Those living far may install a parabolic antenna **103** attached to an SRU. A typical range of a metropolitan area network of this kind is 5 km. The angle of each sector is between 15 to 360 degrees.

The main building blocks of a P-MP network are shown in FIG. 2. Each sector antenna **200** is connected to a Base-Station Radio Unit (BRU) **201** that transmits and receives the radio frequency signals. The subscribers have Subscriber Radio Units (SRU) **202**, connected by a coaxical cable **203** to a Subscriber Access System (SAS) **204** located typically indoors and attached to the user's equipment such as a telephone, computer, ATM switch or a micro-cellular telephone base station. The Base Station includes Base Sector Controllers (BSC), one per sector. The base station mediates between the service provider's backbone network, i.e. ATM network or ISDN network, and the subscribers terminals.

Each sector's spectral allocation may consist of multiple channels as depicted in FIG. 3. For example, a base station carrier may transmit at 25 GHz, occupying 28 MHz of channel width. However, the channel may be further divided into four 7 MHz sub channels so that low-cost STs will not have to transmit and receive at high speeds. The transmit-receive arrangement in this embodiment is based on frequency division duplex (FDD). For example, the base may transmit at 25 GHz and receive from the STs at 26 GHz. Other sectors may reverse role, having the BS transmit at 26 GHz. Each of the sub channels in turn is divided in the time domain. The downstream transmission is a time division multiplex (TDM) channel, essentially a broadcast to all STs tuned to this frequency, while the upstream transmission is a time division multiple access (TDMA), having the STs transmit in turn, as permission is granted from the BSC.

The SRU, shown in FIG. 4, is a small enclosure, roughly a shoe box size **400** with a built-in lens horn antenna. The horn **401** is conical or pyramidal. A dielectric lens **402** provides phase correction. The electronics is mounted on a motherboard **403** with various modules **404** attached. A coaxial connector **405** allows cable connection to the SAS. The horn **401** is fed directly from a diplexer **406** or via a coax/waveguide connection. If a larger antenna is desired, the SRU can be mounted in front of a parabolic reflector with the horn antenna serving as a feed; alternatively a waveguide adapter **407** may be installed to allow direct connection to a larger antenna. Mounting hardware similar to a flood light lamp pointing mechanism is used for alignment towards the base station antenna.

To reduce costs, the SRU does not have a microwave frequency synthesizer. Instead, it relies on the stable BRU frequency as a reference. As shown in FIG. 5, a free running DRO oscillator provides a rough microwave reference. By using dual conversion, a low frequency synthesizer **501** can create the desired offset frequency and fine tune the reception frequency. Examples of oscillator frequencies are shown in FIG. 5. A frequency multiplexer **502, 503** is used for combining all signals onto a single coaxial cable for convenient SAS to SRU connection. The modem recovers a precise carrier of 70 MHz that tracks the phase noise drift of the receive signal, caused mostly by the DRO **500**, and uses this frequency for transmission. As shown by formulas at selected nodes of FIG. 5, the final transmitting frequency is independent of the DRO; therefore it cancels its phase noise. Another embodiment of this invention includes only one conversion, i.e. mixers **505, 506** are **507** are eliminated. Although the phase noise cancellation feature is lost in this case, the benefit is fewer spurious signals, the by-products of mixing and hence less filtering demands.

The SRU structure is application dependent. In many applications, only the digital section **508** changes as the applications change. An example of a digital section to be used for a limited number of ISDN basic rate interfaces is shown in FIG. 6. A microprocessor **600** with built-in ATM formatting capabilities is used for signaling and controlling the entire terminal. The ISDN interface is provided by off the shelf integrated circuit **601**. An ATM access layer for converting the payload to ATM cells can be implemented using a field programmable gate array (FPGA) **602**. For an ISDN payload, a method known as AAL1 is suitable. A media access control (MAC) device **603**, transmits the ATM cells to the modem section **504**, shown in FIG. 5. A Forward Error Correction Device **604** and an encryption/decryption device can also be used. The MAC device can be implemented with a gate array. If cell buffering exceeds device capacity, external memory devices (not shown in the drawings) may be added.

Modem **504** operates differently from upstream transmission as compared to downstream. Upstream transmission entails sending bursts of ATM cells while downstream transmission is continuous. Assuming 4-PSK (QPSK) modulation issued in the downstream direction, it is desired

to maintain the same symbol rate in the upstream direction. However, to achieve good error control, the short upstream bursts (approximately 64 bytes comprising an ATM cell and its overhead) should be heavily protected, which means large forward error correction overhead, resulting in a reduction of upstream payload throughput. This dilemma is sometimes alleviated by use of trellis code modulation (TCM). In TCM, a higher modulation format is used, for example 8-PSK instead of 4-PSK. Some of the extra bits in the 8-PSK modulator are carefully assigned a linear convolutional code based on the length of the intervals between successive symbol transmissions ("phasor"). These distances are slower in FIG. **8**. For example, the squared distance between phasors 0 and 4 is 4 (relative to the radius squared). This technique has some code gain, but is not as effective as Reed Solomon or other similar block codes. In accordance with this invention, the TCM process is modified. First, the code is punctured, i.e. some of the code bits are replaced by data bits. The resulting higher bit rate in turn is used for Reed Solomon (RS) encoding. The overall concatenated code (punctured TCM+RS) has a better code gain then TCM alone for the bit error range of interest to ATM, i.e. a bit error ratio better than 10^{-9}. The modem encoder is shown in FIG. **7**. A converter **700** converts user serial bits to symbols of two or three bits with the pattern 3-3-2-2-3-3-2-2 . . . bits per symbol. A state machine **701** consisting of one-symbol delay elements and XOR gates **703*a*** and **703*b***, performs convolutional coding of bit Y1 during a 2-bit symbol transmission. During a 3-bit transmission the state machine switches to the down position of switches **702*a***, **702*b*** and **702*c***. The resulting state trellis diagram is shown for the first four symbols in FIG. **9**. Each branch represents a symbol transmission. Multiple numbers on the same branch represent parallel alternatives of the same state transition. This diagram has a free distance of 2 or more between any two paths that start at the same node and meet at another node. This distance is similar to QPSK, thus the trellis code will perform roughly like QPSK. So far, one half of the extra 50% bits of the modulation gain from 4-PSK to 8-PSK have been used for TCM. The overall code gain is improved by reusing the other half of the extra 50% bits available, that in a 64-byte transmission, allow 14 RS check bytes for error detection and correction plus a few extra bytes for overhead. The modem counterpart in the Base Station receives this encoded message and decodes the transmission using the well known Viterbi algorithm. Even better code performance suitable for this invention is a use of multidimensional trellis code modulation in which groups of symbols, such as two symbols, are aggregated for each step of the trellis code, keeping the code rate at ⅚. In more general terms, a constellation with M bits per symbol is encoded at a rate higher than (M−1)/M, which is ⅔ for 8-PSK as in some modulation schemes proposed for cable modems.

An alternative to TCM is to use 4-PSK with a symbol rate increased by roughly 10–30%, and using the extra bits as RS check bytes. The advantage of this alternative is a more robust modulation scheme and the avoidance of a complex TCM trellis decoder.

The Base Station demodulator receiving this transmission performs synchronization and decoding. If multipath reflections exist in the propagation path, an adaptive equalizer can be used. Due to the short cell size in ATM transmission, it is not practical to include a long training preamble, thus the equalization is done by means of a multi pass process. First the received signals known as I and Q signals are digitally encoded by A/D converters. The digital samples are then stored and equalizer parameters are estimated. Then the equalizer steps back to the beginning of the message and equalizes using with the estimated parameters. Once this operation is completed, the signals are decoded and demodulated using the Viterbi decoding mentioned above. The equalizer parameters can be stored for next reception from the same source, depending on their time variation.

A reference model for the MAC and related protocol layers is shown in FIG. **10**. Starting from the bottom, a physical medium dependent layer **1010** provides for the radio transmission and modem functions. The MAC layer **1020** (dubbed here "CellMAC")includes FEC (as discussed above), scrambling and framing **1030**. Scrambling is done to randomize the transmission. Framing will be discussed below. The main MAC access attributes are Synchronization **1040**—timing adjustment of the delay to the base station. Encryption **1050** of the ATM cell payload is provided by off-the-shelf DES devices, and public key distribution procedures. Three methods of bandwidth request exist: Contention reservation **1060**, Bitmap reservation **1070** and implied reservation. Each of these will be described below. The only type of upstream data transmission is via granted cell transfer **1080**, i.e. no cell is transferred without a grant (unique permission) from the base station. A data link control **1090** ("CellDLC") layer is provided for optional cell retransmission. This layer is bypassed in most applications, because good error control and detection is already provided by the physical layer as discussed above.

The ATM layer **1005** maintains queues of cells of different service classes. A separate control queue maintains management-type messages between the base and the STs. Upper layers are similar to any ATM application.

The MAC primitives and rules are now discussed. It should be clear that although the MAC layer is described by abstract primitives, each primitive corresponds to a hardware function suitable for implementation by means of a digital gate array. In fact, the first primitive to discuss, ds.block **1110** shown in FIG. **11**, is a typical FEC block code ("ds" stands for downstream). Each slot **1101** represents an ATM cell **1102** with its MAC overhead **1100**. The block is ended by 16 FEC bytes **1120** of RS code. A slight modification is shown in FIG. **12**, in which the slots are "floating" relative to the block timing. This arrangement allows decoupling of the slot size from block size so that mass market low cost DVB-standard FEC decoders developed for satellite television receivers can be used. This standard uses 1 sync byte **1200** and 187 payload bytes, forcing the 59-byte slots **1210** to be randomly truncated, where the missing portion is transmitted in the next block. The slot timing recovery is still possible by a process known as ATM cell delineation, based on the fixed position of the cell header error control (HEC) octet (not shown in the drawings).

The upstream primitive us.atm_cell consists of only one cell because each slot may be used by another ST. As shown in FIG. **13**, the upstream primitive ATM cell consists of 1 octet gap **1300**, 4 octet preamble **1310**, which uses the 8-PSK modulator as a pseudo random sequence of phasors "0" and "4" (essentially BPSK) to allow the demodulator to synchronize the timing and phase of the incoming signal. The block also includes the MAC overhead **1320**, ATM cell **1330**, RS check bytes **1340** and a tail **1350** for TCM decoder state resolution.

The MAC layer maintains a fixed timing relationship between each downstream slot and each upstream slot. This allows it to refer acknowledgments of past transmissions and grants of future transmissions without need to specify the time acknowledged. A fixed system parameter of upstream

delay Nup and downstream delay Ndown, all referred to The Base Station timing, is used, RS shown in FIG. 14. For example, Nup=20 slots offset and Ndown=25 slots offset. All STs adjust their delay to appear in sync at the base.

Bandwidth reservation is done by means of one of three options. Constant bit rate services receive grants periodically without request. The Base Station management program provisions such grants and configures the BSC MAC device to issue periodic grants. In the resulting upstream transmission, the MAC overhead reports the queue status. As a result, the downstream MAC controller can consider this queue status report in prioritizing grants. A second method of requesting a grant is the unsolicited transmission of a short block, us.request, including 1 gap octet, 4 preamble octets, 2 address octets, 2 queue status octets, 2 CRC (error check) octets and 4 FEC (RS) octets. About 5 or 6 of those primitives can fit in one slot time, thus the slot is divided into 5 or 6 "minislots", increasing the opportunities to request bandwidth. From time to time the base station issues global grants indicating a contention slot that allows transmission of these requests. A contention algorithm is used to resolve collisions. This is done by a stabilized slotted aloha or START-3 protocol well known in the literature. For example, an ST maintains a timer that is cleared after every cell it transmits (with queue status indicating more cells waiting). If the timer expires, the ST selects a minislot at random and performs the START3 protocol from the same minislot position in future transmissions. Upon receiving a grant, the ST stops contending until the next timer expiration.

The third method to request bandwidth is the bit map option. Each ST of a limited group (say 110), is provisioned with a single symbol position in a special upstream slot granted as "bitmap" type, as shown in FIG. 15. Each ST of the group with expired timers transmits a signal that is equivalent to asserting one symbol. This method is collision free and thus is very fast and efficient. Since it is not practical to detect a single bit transmission, the bit primitive is actually a short PN sequence, for example 15 symbols long. The receiving modem correlates the received signal by this sequence and records the peaks as individual symbol positions. Although the bitmap sequences overlap, the correlation peaks happen at single symbol times and thus are separable.

The us.admit primitive is shown in FIG. 16. This primitive is sent only if a slot is granted as admission slot. Admission is a process of adjusting ST timing and power before the ST is allowed to receive grants for ATM cell (us.atm_cell) transmissions. There are two types of admission messages, cold and warm. A cold admission is a first time request sent by a newly placed ST. The us.admit includes an 8-octet preamble **1600**, carrying a PN sequence or a fraction of a PN sequence of 32 symbols using only the phasors "0" and "4". A Subscriber Terminal Identifier (STI) **1601** is then transmitted. A cold ST uses a special temporary STI value of 000 . . . 01. A 6-byte IEEE address **1602**, similar an to Ethernet address, installed during manufacturing, uniquely define the ST. A 2 octet cyclic redundancy code (CRC) **1603**, a 4-octet RS FEC check **1604**, and a 2-octet tail **1605** are used. The Base Station Controller grants several consecutive slots for admission requests. These grants are repeated number of times per second. The number of slots (say 4) is such that the delay uncertainty of a new ST will not cause it to step on other slots. If the us.admit primitive is received without error, a downstream message will be broadcast to all STs with STI of 000 . . . 01 and a management service access point identifier to be discussed in conjunction with FIG. 17. This message will repeat the IEEE address and will also include a new STI assignment, a delay figure and a power adjustment figure. If admission failed, a collision indication is placed and the ST must try again in the next granted admission slot group. A START-3 or slotted aloha protocol may also be used to accomplish this function.

A warm admission is used for an ST that already has an STI, but lost sync for some reason. If a warm admission is not successful, a cold admission must be restarted.

The content of a downstream MAC overhead is shown in FIG. 17. The first two octets **1700** represent mostly response to the events that took place Nup slot-periods ago. There are four types of slots: ATM, admission (grouped into four slots), contention(divided to six minislots) and bitmap. All of these slot types have been defined above by the primitive types they carry. The response includes specific bit meaning based on the slot type. The response includes 3 frame bits **1710** used for global synchronization of frame (say every 126) slots (the first bit is toggled, else it is zero, the second bit is eight times slower and the third bit is still eight times slower then the second). These bits allow coordination of events, such as starting of a new connection ahead of time, and among many STs. Next are timing adjust 1720 and power adjust 1730 bits. These bits are valid only if the response is to an ATM slot type. The next octet is a response vector. For an ATM slot this next octet acknowledges reception (0) or error (1). For a contention slot this octet indicates collision so that a certain number of bits in this octet correspond to a minislot and the rest of the bits are undefined. For admission this octet represents collision in any of the four admission slots, and this octet value will be repeated for all contiguous admission slots.

The next 2 octets **1770** include STI **1740** and service access point identifier **1750** (SAPI) which is a MAC subaddress to be further discussed in conjunction with FIG. 19. These fields indicate the destination ST address of the current downstream ATM cell. Some STI values are reserved as group addresses, allowing multipoint broadcast. The ST MAC controller may include several STI registers so that address decoding is ORed with all registers for inputting a cell from the ds.block primitive. The last two octets **1760** are grants for an upstream slot Ndown ahead. The grant includes slot type **1780** (2 bits required, 2 more reserved bits) and STI **1790**. The STI is meaningful only if the slot type is ATM.

A more formal definition of the above fields is shown in Table 1.

TABLE 1

```
ds.CellMAC      {
    3-BIT       FRAME             /* frame timing
                                  /* next 3 nibbles are related
                                  /* to the upstream inf.
                                  /* sent Nup slots ago
    2-BIT       TIMING_ADJUST     /* fine tune ST clock delay
```

TABLE 1-continued

2-BIT	POWER_ADJUST		/* adjust ST transmit power
BYTE	RESPONSE		/* contention COLLISION
vector			
			/* (one bit per minislot) or
			/* COLLISION for us.atm_slot
			/* the next two octets are
			/* related to the ATM cell
			/* attached to this.CellMAC
12-BIT		PAYLOAD_STI	/* ST identifier (address)
NIBBLE		SAPI	/* ST sub-address
			/* the next 2 octets are related
			/* to an upstream slot N_{down}
			/* slot from the current one.
NIBBLE	TYPE		/* slot type, either one of:
			/* us.atm_slot.
			/* contention slot.
			/* bitmap slot
			/* admission slot
12-BIT		GRANT_STI	/* STI for us.atm_slot
		}	

The upstream MAC overhead is depicted in FIG. **18**. It includes the STI/SAP of the sender **1800**, 12-bit buffer status **1810** and a four-bit time stamp **1820**. The buffer status is an indication of all ATM cells waiting for transmission in this ST. If none exists, an all zero status is transmitted. Otherwise a map function is defined to map each queue status to this short message. An example of a map is: each four bits represent one of three service priority levels. For each level, the four bits indicate the level of queues utilization, i.e. 0000 is empty, 0001 is $1/16^{th}$ full and 1111 is $15/16$ full or completely full. The queue capacity can be transmitted once by upper management layers, as it is not varying in time. The time stamp indicates the cell delay variation (CDV) relative to its ideal transmission time in units of slots. If an ST expects a grant for a time sensitive signal at slot x, but receives the grant at slot x+t for a maximum value of T, then t is transmitted as the time stamp. This time stamp allows the BSC to reduce CDV by delaying all cells by T-t slots.

The concept of service access points SAP is shown in FIG. **19**. ATM SAP **1900** carries user's data while a management SAP **1900** carries BS to ST management information. SAPs **1910** and **1920** are reserved for future use. One potential use is a separate SAP for each ATM service category, such as constant bit rate (CBR), variable bit rate (VBR), available bit rate (ABR) and unspecified bit rate (UBR).

In supporting all of these services, a separate SAP identified by a SAP Identifier (SAPI) allows direct connection to each type of queue, e.g. the MAC circuit has one port per SAP. The implementation of the queues is application specific. Queue-control hardware and software are widely available from ATM switch components and LAN interfaces vendors.

The operation of the MAC layer can be described by ladder diagrams. FIG. **20** shows a simple handshake of the ST MAC layer **2000** commanding the ATM layer **2010** to send a cell. The ATM layer **2010** returns a pointer **2020** to the data (cell) in memory and the queue status. The cm.send primitive **2030** can be implemented by a signal on a specified pin in a MAC gate array, and the data/status can be implemented by buses on the same IC. A convenient way to implement the data bus itself is the Utopia Bus as defined by the ATM Forum. The handshake of FIG. **20** implies that a send command comes from the MAC, rather than being initiated by the ATM layer. Therefore, the ATM layer will transmit only when a grant is received. However the ATM layer can indirectly request transfer, as shown in FIGS. **21–22**. FIG. **21** shows an atm.have_data primitive (again, just an interface pin or an electric signal), initiating transfer by requesting bandwidth via the bitmap mechanism combined with status. The MAC **2110** sets the appropriate bit (i.e. it sends the bitmap PN sequence) when the downstream indicates a grant type bitmap. Then the bitmap is set (us.have_data **2120** represents setting the bit) and eventually a grant arrives, enabling the transfer. FIG. **22** illustrates similar schemes, but without a bitmap, which employs contention via a minislot. The bitmap is faster and therefore preferred; however if it is not implemented, the contention mechanism of FIG. **22** is used.

So far the MAC protocol has been described for a symmetrical single channel transmission with frequency duplexing, such as a single 7 MHz channel. However, this protocol can be extended with minor changes to fit other situations. One such occurence is when the downstream signals run N times faster than the upstream signals. Each set of STs receives the fast signals but responds on one of N separate channels. In this arrangement, the slots are simply multiplexed in the downstream in the sequence: SLOT1_CHAN1, SLOT1_CHAN2 . . . SLOT1_CHANN,SLOT2_CHAN1 . . . where the STs can identify their stream of slots by observing the change in the frame bits as discussed in conjunction with FIG. **17**. The first frame bit to toggle corresponds to channel 1. Another extension is an ST that needs to transmit on all four channels. This may happen in some higher capacity applications. As shown in FIG. **23**, for N=4, the N channels are skewed in time so that channel i starts 1/N of a slot time after channel i-1. As a result interleaved cells arrive in the order in which they were transmitted. FIG. **23** shows cells transmitted from a single ST in the order 1,2 3 . . . skipping busy slots. Each transmission in a slot occurs because of a grant to that ST.

Although the MAC protocol as described is a frequency division duplex (FDD) structure, it can also be applied to time division duplex (TDD) with slight modifications. The main modification is that the correspondence of downstream slots to upstream slots for purpose of response and grants is defined relative to upstream slots on the same frequency channel. If the upstream and downstream directions have

asymmetrical bandwidth allocation, the downstream being N times wider than the upstream, then only one of the N downstream ATM cells carries a MAC overhead and the other N-1 ATM cells are transmitted without any MAC overhead.

In accordance with this invention, grants are not directed, i.e. when an AT receives a grant to transmit a us.atm_slot primitive, the ST chooses which one of the currently available ATM cells to transmit. This freedom preserves link bandwidth by avoiding transmission of the cells virtual circuit number (VPI/VCI in ATM terminology). However, a potential problem may arise if a grant intended for constant bit rate (CBR) service arrives too early and is used for an other service (say ABR) only to find out later that there will be no other grant for this ST. This problem is solved by the following algorithm. The BSC maintains a list of all CBR connections and their period and the last slot that was used in the upstream for this connection. The BSC calculates the new expected grant time and the BSC normally grants this slot to the ST with this circuit. However, if due to conflicts of two or more CBR circuits at different rates whose expected slots coincide from time to time, only one of them will be granted and the rest will be delayed within a time window W1 of 10 slots. Each CBR circuit handler at the ST (such as the AAL device **602** in FIG. **6**) maintains a window of period W2 slots (say W2=10, but needs not be equal to W1) starting with the expected slot. Only grants for slots within this window may be granted to this connection. If multiple connections have overlapping windows, the window that started earliest, i.e. the oldest window will get the grant, as long as it has not expired will get the grant. This process causes cell delay variation anytime the grant is not available for the circuit at the beginning of the window. The CDV can be eliminated using the time stamp mechanism discussed above.

The MAC protocol can be implemented in several ways. One approach is to delegate all time critical functions to a field programmable gate array (FPGA) with attached memory devices, encryption/decryption devices and forward error encoding/decoding devices. The FPGA block diagram for a subscriber terminal is shown in FIG. **24**. The ds.block primitive is decoded externally and the recovered data, clock, error detection and timing signals **2400** are brought to the FPGA. If needed, the demodulator **2410** is informed specifically of which ST is expected in the current slot time. This enables the demodulator **2410** to store and retrieve the contents of the latest known power level of this ST, thereby reducing the chance of error or the acquisition time of power level and frequency offset. The slot timing is recovered first by a timing and cell delineation circuit **2401**, with the aid of a cell header error control checker **2402**. Next, the address field STI in the MAC overhead is checked by an address decoder **2403** to check if the currently received cell should be dropped for local use. Several STIs are compared—one is the local STI (which equals 0 if the admission process has not been completed) Several group addresses may also be checked. A dropped cell is delivered to the application via the RxData bus **2404** which may be the Utopia Bus. Next the grant type and grant STI are examined by the address decoder **2403**, and if the grant is locally valid, it goes to a grant buffer **2405** and delayed by Ndown slots compensated to the ST's specific distance from the base station by a delay generator **2412**, whose specific delay value has been set by an external microcontroller during the admission process. The grant type and timing are signaled to the various upstream primitive generators by a grants bus. This controls the generation of bitmap requests **2406**, minislot request **2407** (us.request), us.atm **2408** and us.admit **2409**. Each of these primitives is generated by a bit sequence loaded from an external microcontroller except for status and data that are passed directly from the application. The transmitted signal with appropriate timing indications is sent to the modulator **2411** which is also performs encoding and scrambling.

The Base Station MAC control section is shown in FIG. **25**. This section may be implemented on a printed circuit board level, including multiple memory and FPGA devices as may be required. The MAC controller receives MAC primitives from the burst demodulator via a bus **2500**. This bus indicates data, timing, estimated reception power and error messages. A timing generator **2501** controls the reception and transmission of MAC primitives. It is synchronized via external timing reference means and control signals **2502** allowing the slot timing to be frequency locked to a global synchronization such as the telephone network primary clock or global positioning system. If the reception slot is an admission slot, the admission parameters are estimated based on the modem input **2515** by an estimation circuit **2502**. If admission request is detected, it is passed to the Base Sector Controller via an indication bus **2507**. In a us.request reception, the minislot processor **2505** decodes the request and deposits the queue status from the request into a register bank called queue table **2508**. Similarly, if a bitmap slot is received, all set bits are written into the queue table **2508** by the bitmap processor (decoder) **2506**. Other conditions on a reception, such as normal us.atm_cell cell reception and loss of data, are decoded by a Status Reader **2504**. The Status is written to the queue table **2508**, and the indication of success or failure of reception is indicated to the Response Generator **2503**. The response generator updates the response field in the ds.block primitive via a multiplexer **2509**. A grants processor **2510** scans the queue table and selects the ST to receive a grant. That ST's address (STI) is written in the address field of the multiplexer **2509**. The grants processor **2510** makes its grant decision not only according to the queue content **2508** but also by a connection table **2511** that lists all constant bit rate virtual circuits (VC). Thus, for each such VC it checks whether the next upstream slot to be granted should get a grant related to this VC. Only if none of the CBR VCs has a non-expired window of transmission, a grant based on the queuing table **2508** is selected. Once a grant is made, the related STI and SAPI are read from the connection Table **2511** and sent to the multiplexer **2509**. The grant processor **2510** can be implemented by a combination of an FPGA and a RISC processor. The FPGA performs a priority encoding (decision) of the next ST, while the RISC processor performs the background tasks of maintaining the queue table. For example, if a particular ST is selected by the Grants Processor **2510**, the queue status entry for that ST is modified according to the following algorithm:

1. Modify Queue status for this ST as it would appear after one cell is subtracted from the highest priority queue.
2. If a nuw status is received from the same ST (via us.request or us.atm_cell), the new status overrides the modified one.
3. If no valid cell was received from the ST at the granted slot (most likely due to link error)and no new status update of step 2 was done, then restore original queue status.

Cells to be transmitted downstream arrive from the application layer which can be an interface circuit to the ATM network. The cells are delivered in the order in which they are received by a cell input circuit **2512**, to which the cell

destination address (ST and SAPI) is added by an ST Mapper **2513** based on a connection table **2511**. There are two ways to implement the STI Mapper, depending on the choice of ATM address space in a particular ATM application. If all STs share the same address space (VPI/VCI), then the Connection Table **2511** assigns an STI/SAPI to each VPI/VCI. In other applications, the address space may have only local context (two STs may reuse the same VPI/VCI of their ATM cells for totally unrelated connections), then the ATM application must provide the STI/SAPI for each cell to be sent. The application in this case is most likely an ATM switch or an ATM statistical multiplexer that can treat each ST as a logically separate port.

The multiplexed downstream transmission is handed to the modulator, scrambler and FEC encoder via a transmit bus **2514**. If needed, the cell input circuit **2512** may add encryption to the payload field (48 bytes) of the ATM cell.

A base station Controller, shown in a block diagram in FIG. **26**, consists of one or more single channel controllers **2600**, and a linear frequency division multiplexer **2601**. Each single channel controller **2600** includes an IF circuit **2602** (amplifiers, filters, AGC circuits as required), a modem **2603** having QPSK continuous modulation for downstream transmission with RS FEC, scrambling and sync as described above in conjunction with the ds.block, and a burst modem with TCM and RS decoding and the ability to detect the various upstream primitives described above, a MAC Controller **2604** as described in conjunction with FIG. **25**, and a Control Unit **2605**, based on a microprocessor circuit and connected via data or I/O buses to all other subsystems (connection not shown in FIG. **26**). An Interworking Function **2606** converts the ATM cells to and from the MAC Controller **2604** to whatever format the carrier network requires, such as ATM, Frame Relay or narrow Band ISDN. This function is thus application specific and, in most cases, can be found in existing ATM switches and multiplexers. A line interface **2607** converts the traffic of the Interworking Function **2606** to the network format such as T3/E3 interfaces. As an option for improving cellular network coverage by minimizing interference from geographically adjacent cells, an Adaptive Radio-resource Manager (ARM) Controller **2608** may be included. The ARM Controller is a microprocessor application that responds to commands from a network management system application that coordinates frequency/time activities among multiple sectors and cells. For example, if the network management system finds that a particular ST interferes with another base station, the network management system may instruct that base station to skip those cell slots affected or shift the ST entirely to another frequency. The ARM controller **2608** makes the Base Station Controller capable of receiving such commands from an external controller. The key element for ARM operation is global synchronization of all sectors and cells, as described above. By having all base stations maintain a fixed relationship of the MAC frame/multiframe bits to the global time reference, it is possible to devise algorithms to map transmission from an ST in one sector to interference in another sector or cell. Thus the timing generator **2501**, shown in FIG. **25**, is locked to global time and, in effect, acts as a real time clock. It should be clarified that all real time clocks need not be in identical phase in each cell, as long as they maintain the same difference with each other for a long time. Multiple channels are processed by repeating the same channel structure **2600** as many times as needed. These channel controllers may need to share or switch data among themselves, which can be accomplished via a bus **2610**. Finally, all controllers can share the same enclosure or equipment rack to form a base station. Each Base Sector Controller has a coax cable leading to a Base Radio Unit (BRU) **2611**. The BRU includes IF circuits, converters, frequency synthesizer, amplifiers and a diplexer, driving the sector antenna via a waveguide. Such BRUs are commercially available. For example, Netro Corporation of Santa Clara Calif. has a BRU for 38 GHz which, with proper scaling, can be redesigned for other frequencies.

The sector antenna is a pyramidal horn with a rectangular aperture and optional modifications as described below. To minimize interference and to maximize frequency reuse, special care is taken of the Base Antenna. As seen in FIG. **27**, one potential mode of interference is a subscriber terminal **2700** receiving from Base Station A with radiation pattern **1**, which also receives from base station B with radiation pattern **2**. If pattern **2** is in a different frequency than **1**, interference is negligible. It is assumed here that base stations located further away, say another cell diameter behind B, are too far to cause significant interference. In this simple scheme, two frequencies are sufficient to avoid interference. In fact, when multiple cells are drawn together, as shown in FIG. **30**, two frequencies are sufficient to avoid the interference mode of patterns **2** to **1** in FIG. **27**. FIG. **30** is a lattice based on a four cell structure **3000**. This structure has one drawback: some of its sectors are wider than the others. If this is not acceptable, a three-frequency symmetrical solution also exists, as shown FIG. **31**.

The Antenna needs to have a wide pattern in the horizontal dimension, such as 30, 60 or 90 degrees. In the vertical dimensions it may stay narrow, say a 12 degrees beam width, allowing it to improve the gain. However, nearby STs may fall into zeros in the radiation pattern, as shown in FIG. **28**. This is avoided by allowing a small phase deviation in the horn aperture. A quarter wavelength seems a good compromise between main lobe beam spread and side lobes flattening. This reduction is accomplished by a choice of horn geometry or by intentional aberration in a dielectrical lens. A complete antenna is shown in FIG. **29**. Its dimensions are about 10 to 20 cm in the longest direction, thus it is fairly small. The pyramidal horn **2900** may include a lens **2901** of near cylindrical shape and absorbing walls **2902**, for adjusting beam width and allowing said radiation pattern to roll off in the horizontal dimension to avoid interference from a pattern **3** to ST **2700** shown in FIG. **27**.

We claim:

1. A wireless metropolitan area network including:

at least one base station having a plurality of sector antennas and a MAC controller, said station transmitting and receiving based on frequency division duplex (FDD) by means of said sector antennas;

a plurality of subscriber terminals (STs) located within a sector area, each ST including:

a directional antenna,

a MAC processor, and

circuitry for requesting bandwidth through a plurality of contention slots, said circuitry receiving transmission grants from said MAC controller and transmitting ATM cells including a MAC overhead and forward error correction per ATM cell to said base station;

wherein each ST transmits one ATM-cell burst per ATM-type grant received from the base station, said grant information including a grant type, and said ATM-cell burst is received by the base station at a fixed time interval from the transmission of a corresponding grant from the base station to the ST.

2. The network of claim **1**, wherein said MAC controller includes support for at least three types of grants.

3. The network of claim 1, wherein said MAC controller includes support for ATM cell slot, contention slot and admission slot grants.

4. The network of claim 1, further including bitmap slots.

5. A subscriber terminal (ST) for a wireless ATM metropolitan area network including:

subscriber interfaces;

a MAC framing and timing processor for transmission of ATM cells;

forward error correction circuits; and

a radio unit having an enclosure, mounting and alignment hardware, and an attached lens horn antenna,

wherein the ST transmits one ATM-cell burst per ATM-type grant received from a base station, said grant information including a grant type, and said ATM-cell burst is received by the base station at a fixed time interval from the transmission of a corresponding grant from the base station to the ST.

6. The structure of claim 5, wherein said radio unit includes:

a horn antenna wherein the horn structure is an integral part of the enclosure of said radio unit;

a dielectric lens attached to said horn structure; and

transmitter up conversion circuits and receiver down conversion circuits.

7. The structure of claim 6, further including a microprocessor having built-in ATM formatting capabilities.

8. A method of for transmitting constant bit rate ATM cells over a point-to-multipoint network including the steps of:

(a) transmitting a grant to a subscriber terminal within a first fixed time window of the ideal transmission time for a virtual circuit; and

(b) having said grant be used by said virtual circuit that also maintains a second time window only if said second time window has not expired.

9. The method of claim 8, wherein during step (b) if more than one virtual circuit exists on a subscriber terminal the grant is given to a virtual circuit with the oldest non-expired window.

10. The method of claim 9, further including the step of transmitting a time stamp with each of said ATM cells that has used said grant, wherein cell delay variation is reduced by adding a compensating delay to said cell upon arrival at the receiving end of said network.

11. The method of claim 8, wherein said first time window and said second time window are of equal time duration.

12. A method for scheduling transmission of ATM cells for CBR services from subscriber terminals to a base station over a point-to-multipoint network over a shared medium wherein said base station can grant the time slot of said transmission to any CBR virtual circuit, the method including the steps of:

(a) creating grants for multiple CBR virtual circuits at the base station, wherein each grant is first scheduled for a time slot that minimizes cell delay variation for a corresponding virtual circuit; and

(b) if two or more grants are scheduled for a first time slot, re-scheduling at least one of said grants to a second time slot;

wherein each ST transmits one ATM-cell burst per ATM-type grant received from the base station, said grant information including a grant type, and said ATM-cell burst is received by the base station at a fixed time interval from the transmission of a corresponding grant from the base station to the ST.

13. The method of claim 12, further including the steps of:

(d) transmitting a grant to a subscriber terminal within a first fixed time window of the ideal transmission time for a virtual circuit; and

(e) having said grant given to said virtual circuit that also maintains a second time window only if said second time window has not expired.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 5,936,949
DATED : August 10, 1999
INVENTOR(S) : Pasternak, Eliezer, Feeney, Stuart M., Ben-Efraim, Gideon

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 14,
Line 57, delete "nuw" and insert -- new --.

Signed and Sealed this

Second Day of April, 2002

Attest:

JAMES E. ROGAN
Director of the United States Patent and Trademark Office

Attesting Officer

United States Patent [19]

Mayo

[11] **Patent Number:** 4,792,946

[45] **Date of Patent:** Dec. 20, 1988

[54] **WIRELESS LOCAL AREA NETWORK FOR USE IN NEIGHBORHOODS**

[75] Inventor: **Scott T. Mayo**, Raleigh, N.C.

[73] Assignee: **Spectrum Electronics, Inc.**, Raleigh, N.C.

[21] Appl. No.: **35,447**

[22] Filed: **Apr. 7, 1987**

[51] **Int. Cl.**[4] **H04J 3/02**

[52] **U.S. Cl.** **370/86**; 370/85

[58] **Field of Search** 370/94, 95, 86, 85, 370/88; 455/33, 56; 340/825.05

[56] **References Cited**

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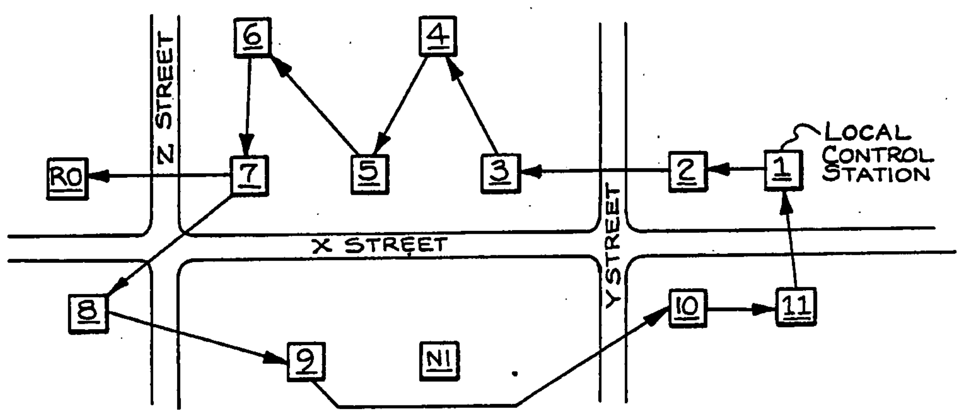
Primary Examiner—Douglas W. Olms
Assistant Examiner—Wellington Chin
Attorney, Agent, or Firm—Bell, Seltzer, Park & Gibson

[57] **ABSTRACT**

A local area network for digital information transmission to and from each of a plurality of building units in an area, such as homes in a neighborhood is provided, wherein all connections between units are wireless. Each unit is provided with and fm transceiver station, which is connected with an electrical system in said unit, such as a security system or a power distribution system in such a way that information can be gathered from said system and commands delivered to said system. Each transceiver is adapted to operate at a power level and on a frequency which does not require an FCC license. Each transceiver includes programmable means adapted to cause said transceiver to recognize transmission specifically addressed to it by other stations in the network, and to cause said transceiver to generate and send transmissions specifically addressed to other transceivers in the network. Thus, the transceivers on the network are serially linked in a loop, and commands for the system in any building unit and data from any system in any building unit may be passed from unit to unit about the loop in either of two directions.

23 Claims, 3 Drawing Sheets



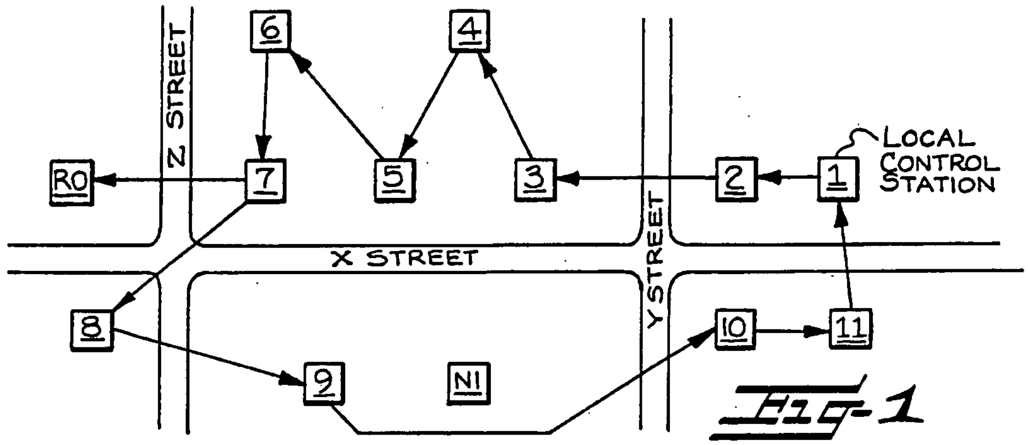


FIG-1

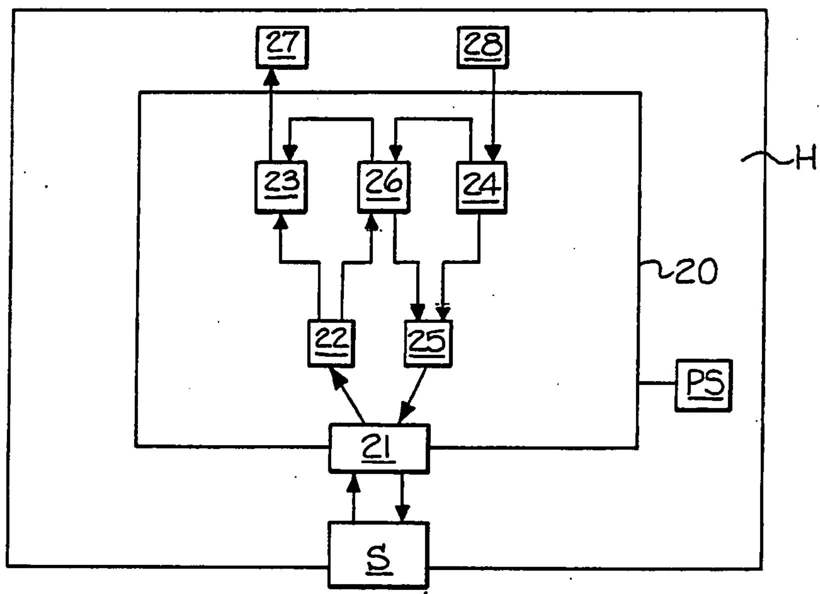


FIG-2

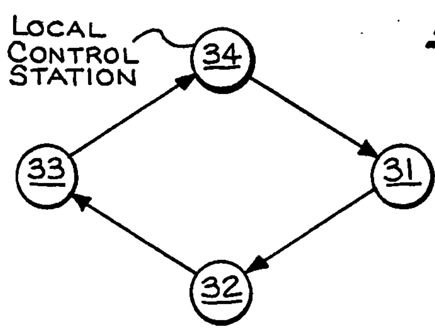


FIG-3

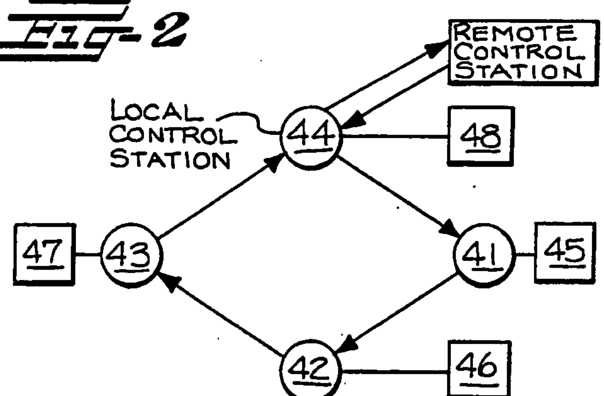
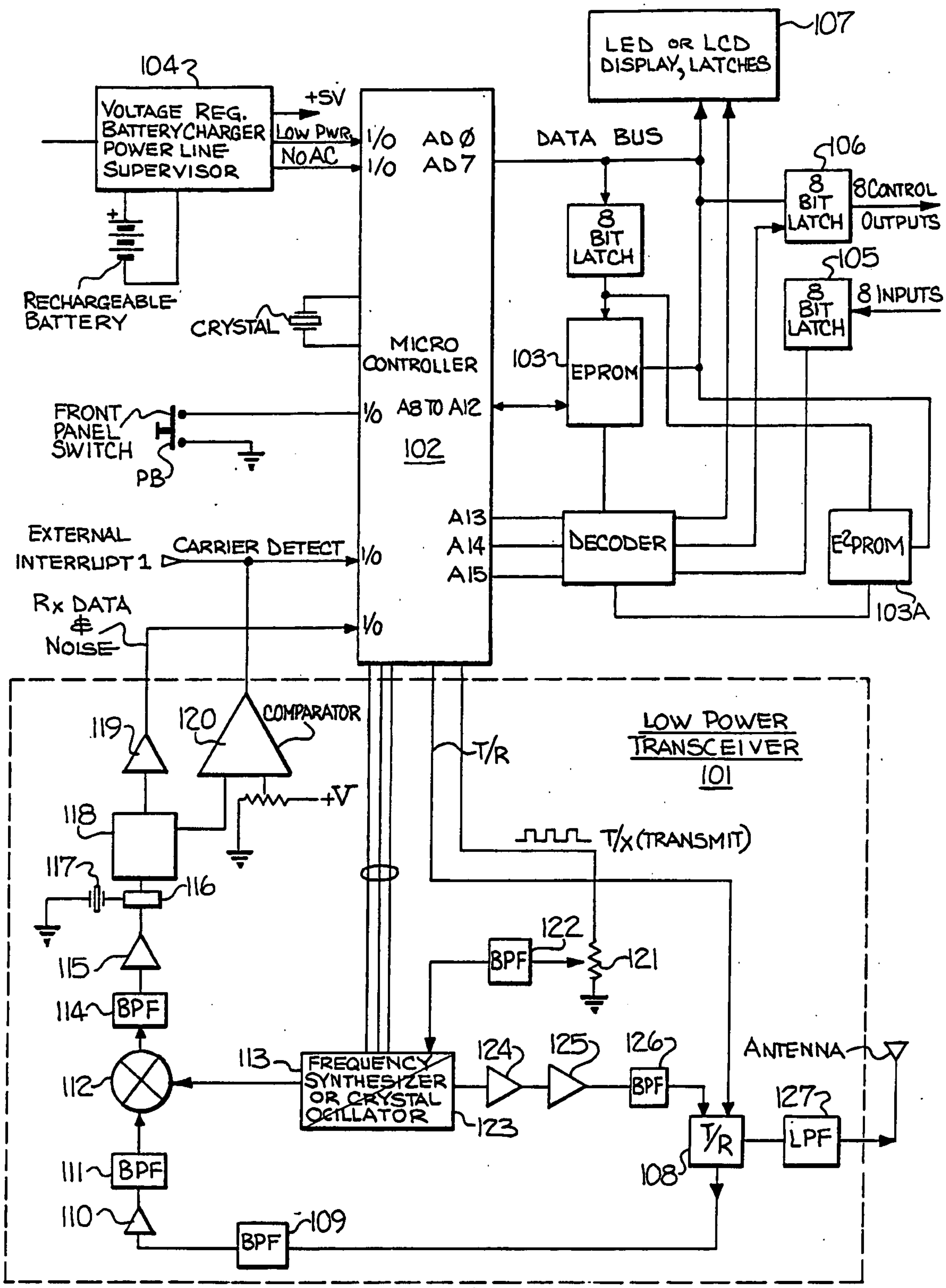


FIG-4



LED OR LCD DISPLAY, LATCHES
107
104
VOLTAGE REG. BATTERY CHARGER POWER LINE SUPERVISOR
+5V
LOW PWR
NO AC
I/O
I/O
AD Ø
AD 7
DATA BUS
106
8 BIT LATCH
8 CONTROL OUTPUTS
8 BIT LATCH
105
8 BIT LATCH
8 INPUTS
RECHARGEABLE BATTERY
CRYSTAL
MICRO CONTROLLER
103
EPROM
FRONT PANEL SWITCH
PB
I/O
A8 TO A12
102
A13
A14
A15
DECODER
E2PROM
103A
EXTERNAL INTERRUPT 1
CARRIER DETECT
I/O
RX DATA & NOISE
I/O
119
120
COMPARATOR
LOW POWER TRANSCEIVER
101
T/R
+V
118
T/X (TRANSMIT)
117
116
122
BPF
121
115
114
BPF
113
124
125
126
ANTENNA
112
FREQUENCY SYNTHESIZER OR CRYSTAL OSCILLATOR
BPF
123
127
T/R
LPF
111
BPF
108
110
BPF
109

FIG-5

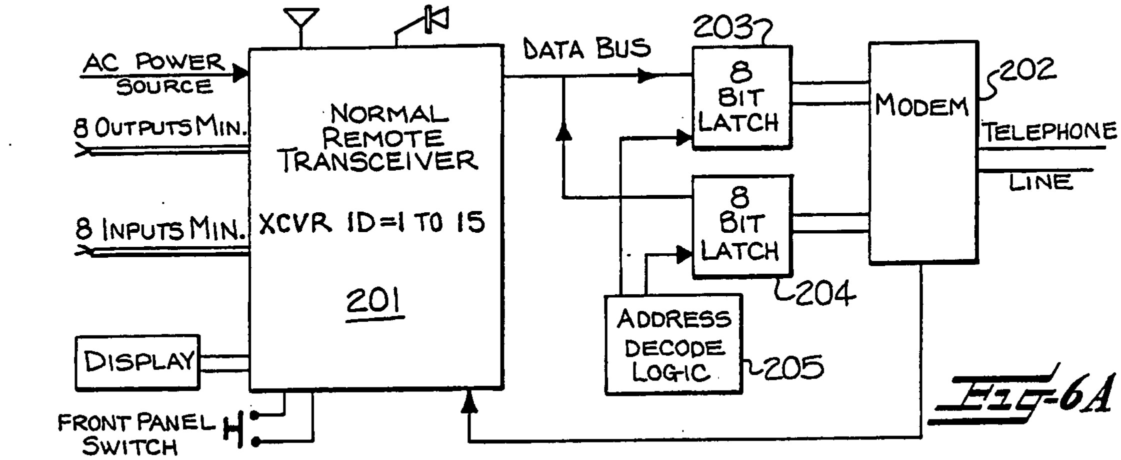


Fig-6A

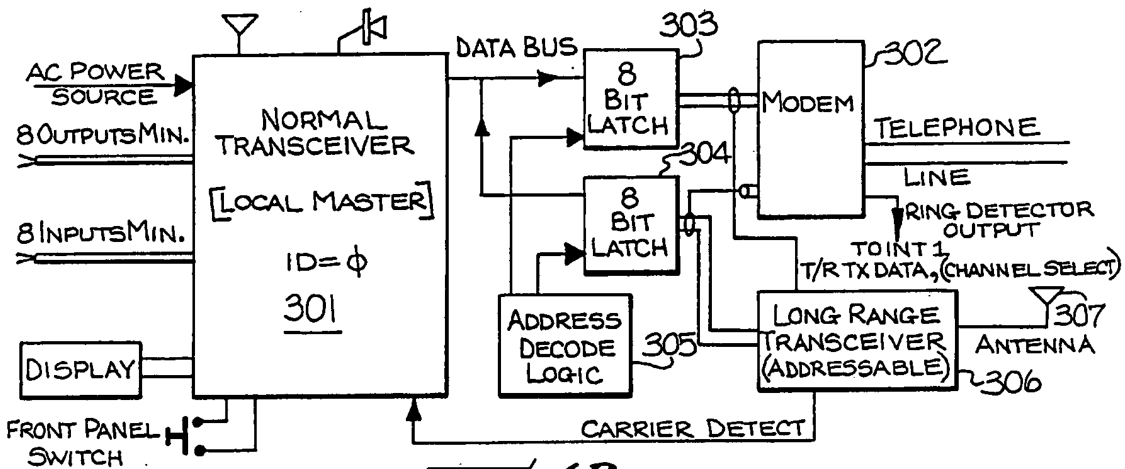


Fig-6B

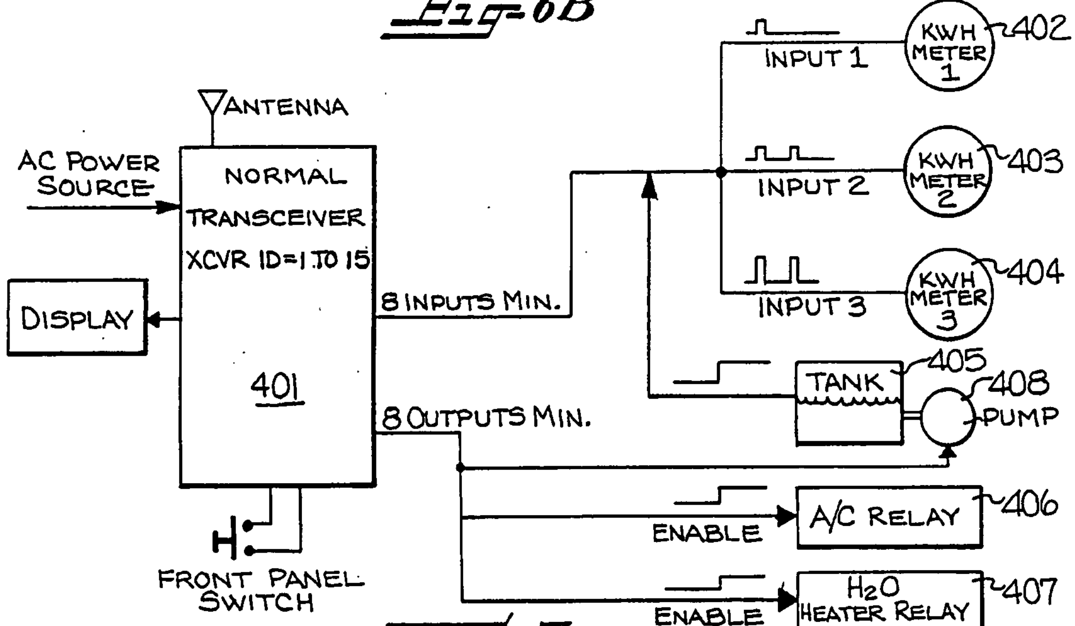


Fig-7

WIRELESS LOCAL AREA NETWORK FOR USE IN NEIGHBORHOODS

FIELD OF THE INVENTION

This invention relates to a low-cost local area network of an exceptionally high level of security and reliability for data transmission to and from the homes in a neighborhood, the offices in a business complex, or the apartments in a high-rise building, for example. More particularly, the invention comprises a network including a plurality of serially-linked, wireless fm transceivers, of a power level and transmission frequency band not requiring an FCC license, one each located in each of a plurality of the homes in a neighborhood, or the like and is comprised of these low power transceivers in a way to cover a much larger area than is possible with standard polling systems. A principal use of said local area network, which preferably incorporates a system for periodically assessing the functional status of each transceiver in the network, is as a neighborhood security system capable of recognizing and acting upon a breach in the security of any home in the network, whether by fire, for example, or by reason of a break-in. Other uses include public-utility-related functions, such as kilowatt-hour usage data transmissions or load-control command transmissions, and other unusual event cognizance such as, for example, that related to the health of residents in a retirement community. Each transceiver is adapted to communicatively interface with a variety of home security systems, or other locally-installed electronic systems such as power meter wheel revolution counters or the like.

BACKGROUND OF THE INVENTION

In general, local area networks interconnect via cables. Such cables are, however, expensive to install even in high-density office buildings, and would be even more expensive in low-density neighborhoods. They are also subject to physical disruption.

Turning now to available home security systems, many provide only a local action in response to a breach of security, such as by turning on an alarm or turning on the lights. If no one is home, and no neighbor notices, such local action is relatively ineffective. Others provide for transmission of information concerning a security breach to some central station via the telephone lines connected to the home the security of which has been breached. However, such land lines are subject to disruption, via deliberate cutting or weather-felled trees, for example. Two-way, long-distance radios can, of course, be used to act upon breaches. However, such radios are expensive, require an FCC license, and almost invariably utilize a radio channel shared by an indefinitely arge number of parties.

The neighborhood security network provided by the invention serves to supply local alarms in more than one home for any breach in a given home, and thus need not report to a central station. Where optionally arranged to so report, it is adapted to make available all the phone lines connected to the homes in the network to report a breach in any given home. It may also utilize but a single two-way long-distance fm transceiver to report to a central station a breach in any given home, thus spreading the cost of such transceiver among all the homes in the network, and minimizing potential licensing difficulties.

Turning next to public-utility-related usage, utility-originated commands for home load control are now typically transmitted over either phone lines or power lines. Both are slow. Further, both are subject to physical disruption, and both present the possibility of spurious signals, or cross-talk, or the like. Occasionally, expensive one-way UHF radios are used, and, of course, even more expensive two-way radios requiring licenses could also be used.

With regard to power usage, on the other hand, electric and gas meters are normally read by human eye by a reader actually visiting the meter. In recent years, a number of schemes have been contemplated to accumulate usage data, as by counting wheel revolutions per unit time and storing such information as a preliminary necessity for actually automatically transmitting such information upon command of a remote central station. Such could be done via power or phone lines, with the same above-mentioned potential problems. Similarly, an expensive two-way long-distance radio would be supplied to each home, though a license would still be required.

The neighborhood network of the invention can readily serve both purposes, with communication with a remote central station provided by a single, licensed transceiver per neighborhood, the cost of which is shared among up to sixteen homss. Outbound power usage data or inbound load control commands can be passed respectively from or to individual homes via the serially linked lower power, license-free FM transceivers in each home.

SUMMARY OF THE INVENTION

The present invention provides a local area network for digital information transmission to and from each of a plurality of homes in a neighborhood, or a plurality of offices in a complex, which network is wireless, secure, reliable, and relatively modest in cost. As generally contemplated, the network comprises a plurality of transceiver stations, one located at each of the plurality of neighborhood homes.

Each transceiver station includes a radio transmitter means adapted to transmit information in digital form, and a radio receiver means adapted to receive information in digital form. The transmitter means is adapted to selectively address the information it transmits to at least either of two other proximitely located transceiver stations from among the plurality, while the receiver means is adapted to specifically recognize informtion transmitted to it from at least either of two other proximately located transceiver stations from among the plurality.

Each transceiver station further includes interface means interconnecting the transceiver with at least one electrical system within the home where such transceiver is located, such interface means being adapted to accept data from the electrical system and deliver commands to the electrical system. First means interposed between the interface means and the transmitter modulatingly conveys said data from the interface to the transmitter, while second means interposed between the interface and the receiver demodulatingly conveys said commands from the receiver to the interface.

Still further, each transceiver station also includes programmable control means adapted to cause the transmitter to recognizally and selectively re-transmit data and commands received by the receiver, in a predeterminable manner.

As a result, the plurality of transceiver stations can be serially linked in a loop, and commands for any of said systems and data from any of said systems can be passed from station to station about the loop in either of two directions, such as, for example, in a clockwise or right-hand direction or in a counterclockwise or left-hand direction.

In one embodiment, a local area neighborhood security network, the electrical system located in each of the plurality of homes in the network is an individual home security system for detecting fires or break-ins or the like. Such system is connected via the interface means to the transceiver station, and the data from said system which is modulatingly conveyed by the first means interposed to the transmitter is information concerning alarm conditions. Likewise, the commands demodulatingly conveyed by the second means interposed from the receiver to the interface are alarm termination commands. Preferably, each transceiver station further includes indicator means adapted to recognizably and selectively indicate the existence of an alarm condition in the security system of any of the other homes of the plurality. In this way, an alarm condition in any of the home security systems of the plurality of homes can be selectively and recognizably indicated in at least one other of said plurality of homes.

In another embodiment, a local area utility service network, the electrical system located in each of the plurality of homes in the network is that associated with an individual utility distribution apparatus within such home, such as electric power or natural gas distribution apparatus. Such system is likewise connected via the interface means to the transceiver station, and the data from said system which is modulatingly conveyed by the first means interposed to the transmitter is information concerning utility usage. Similarly, the commands likewise demodulatingly conveyed by the second means interposed from the receiver to the interface are appliance enabling and disenabling commands.

In any embodiment, a predetermined one of the plurality of transceiver stations can be selected to act as a local control station for the network. Such transceiver station further includes means for generating commands addressed to any of the other transceiver stations, and also means for retrievably storing data recognizably received from any of the transceiver stations in the network.

Additionally, or in the alternative, the network can further comprise means interconnecting a remote central station, such as a fire station, for example, or a utility office for further example, with any of said transceiver stations of said plurality. Such means interconnecting are adapted to transmit to the remote central station data from any of the transceiver stations, and are further adapted to receive from the remote central station commands addressed to any of the transceiver stations. Such means interconnecting can be, for example, a suitable telephone line with modems at each end, or, for further example, a long-distance, two-way radio transceiver.

Further still, the local area network of the invention can further comprise verification means for periodically assessing the integrity of the network by ascertaining the operability of each transceiver station therein. Such verification means includes means for generating a status command addressed to a first transceiver station among the serially-linked plurality of stations in the loop. Both said first station and each other station include means directing their respective transmitters to address the status command to the next downstream station in the loop and to re-transmit such command thereto. Also, both the first station and each other station further include means for recognizing when said next downstream station fails to re-transmit the status command and means for generating a fault signal upon recognition of such failure.

Each transceiver other than the first includes means for directing its transmitter to address the fault signal to the next transceiver upstream in the loop and to transmit such signal thereto. Said first transceiver includes means for directing the fault signal back to the means for generating the status command. Such generating means also includes means for recognizing, storing, and acting upon said fault signal.

The means for generating the status command, including the means for recognizing, storing, and acting upon the fault signal, can be located within the local control station, whereupon said first transceiver station is the local control station itself. Alternatively, the means for generating the status command, including the means for recognizing, storing and acting upon the fault signal, can be located in the remote central station, whereupon said first transceiver station is the transceiver station associated with the remote central station via the interconnecting means.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic representation of a neighborhood in which a plurality of homes are included within the local area network of the invention.

FIG. 2 is a schematic representation showing in block diagram form the transceiver station in each home of the plurality.

FIG. 3 is a schematic representation of a simplified version of the local area network of the invention.

FIG. 4 is a schematic representation of a simplified version of the local area network of the invention including means for interconnecting the network with a remote central station.

FIG. 5 is a block diagram showing one preferred form of a typical transceiver utilized in the network.

FIG. 6A is a block diagram showing a preferred form of interconnection between a typical transceiver and a phone line.

FIG. 6B is a block diagram showing a preferred form of interconnection between a transceiver acting as local control station and both a phone line and a long range transceiver.

FIG. 7 is a block diagram showing a preferred form of interconnection between a typical transceiver and a utility distribution system.

DETAILED DESCRIPTION OF THE INVENTION

While the present invention will be described more fully hereinafter with reference to the accompanying drawings, in which a preferred embodiment of the present invention is shown, it is to be understood at the outset of the description which follows that persons of skill in the art may modify that which is herein described while still employing the invention as such and achieving the salutary results thereof. Accordingly, the description which follows is to be understood as being a broad, teaching disclosure directed to persons of skill in the appropriate arts, and not as limiting upon the present invention. A general description of the invention

will be set forth initially, to be followed by a description of alternative embodiments and optional features, and in turn followed by a more specific description of certain transceiver circuitry.

Referring to FIG. 1 of the drawings, a neighborhood is shown in schematic plan form, including thirteen homes, eleven of which, numbered 1 through 11, are actively included in the local area network. Each home in the network has a transceiver station installed therein. The transceiver station at home 1 has been selected to act as the local control station normally included in the network. The arrowed lines from home to home indicate that the plurality of stations in the network can be serially linked in a loop, with the arrows indicating a direction in which data and commands can be passed about the loop. Such direction can, of course, be of opposite hand.

The home labeled RO is, optionally, associated with a receiver only, such that cognizance can be maintained there of data and commands traveling about the loop. Such could, instead of a home, be, for example, a guard station at the entrance to the neighborhood. Such home does not otherwise participate in the network. The home labeled NI has no transceiver and is not involved in the network to any extent. Naturally, the homes 1 through 11 depicted in FIG. 1 could as easily represent offices in a complex or warehouse units in an industrial park, for example.

Referring to FIG. 2 of the drawings, a schematic representation of one of the transceiver-station-equipped homes in the network is shown. Within home H is installed transceiver station 20, which is connected via interface menns 21 to home electrical system S. System S can be typical individual home security system of any known type, which detects, for example, a fire or a break-in, and develops a signal which sounds an alarm, or turns on the lights, or the like. System S can also be associated with a utility distribution system in home H, capable of, for example, ascertaining and reporting on kilowatt-hour usage, or of turning on or shutting off the air conditioner, for further example.

The arrowed lines between interface 21 and system S indicate the flow of system data to interface 21 from system S, and the flow of commands from interface 21 to system S. It will be readily appreciated that interface 21 can include some combination of suitably arranged wires, switches, connectors, relays and the like, depending upon the actual nature and extent of system S.

Within the transceiver, as indicated by the arrowed lines, data from system S is modulatingly conveyed from interface 21 to transmitter 23 via means 22 interposed between interface 21 and transmitter 23. On the other hand commands are demodulatingly conveyed from receiver 24 to interface 21 via means 25 interposed between receiver 24 and interface 21. Transmitter 23 is, in turn, connected to a transmitting antenna 27, which may be exterior to the home, but which is in the interest of security, preferably located interior to home H, while receiver 24 is connected to a receiving antenna 28, likewise preferably located interior to home H. Transceiver 20 is also connected to a suitable source of power, PS, preferably including backup battery capability.

Each transceiver station further includes programmable means 26 for directing transmitter 23 to addressably re-transmit certain data and commands received by receiver 24, as will be explained more fully hereinafter. When transceiver 20 is the transceiver designated to act as local control station for the network, programmable means 26 will also include means, not shown, for generating other commands, either to the transmitter 23 or to the system S and will further include other means, also not shown, for retrievably storing data either from the system S or from receiver 24, the operation of all of which will be further appreciated by reason of the detailed explanation of the network in operation, as set forth elsewhere hereinbelow.

The transmitter included in each transceiver station in the local area network of the invention is of a power and frequency such that a Federal Communications Commission license is not required, in the interest of both economy and network installation simplicity. Thus, the frequency of operation will be, for example, selected from among permissible bands within the spectrum segment from 100 kilohertz to 1000 megahertz, and the power level will be severely restricted, such that the effective range is generally less than a mile and typically on the order of about 200 to 1000 yards.

Such range should be quite adequate in most neighborhoods to easily include the transceiver stations located proximately either side of any given transceiver station, whether such neighborhood be densely populated as in an apartment building or relatively sparsely populated as in many rural communities. When, however, the distance beteeen homes having stations is greater than the effective range, such as might be the case, for example, with regard to homes 9 and 10 shown in FIG. 1, then it will be necessary to employ a suitably configured and located repeater station, not shown. Naturally, care must be exercised with regard to the security of the power source for, and access to, any such repeater station.

The transmitter included in each transceiver station must also be capable of transmitting information in digital form, and adapted to address such information to either of two proximately located other transceiver stations. Similarly, the receiver included within each transceiver station must also be capable of receiving information in digital form, and be adapted to specifically recognize information specifically addressed to such receiver received from either of two other proximately located transceiver stations within the network.

When, for example, in the interest of reliability, the respective receivers and transmitters are selected so as to operate in frequency modulation mode, the information in data form can be modulatingly impressed upon the carrier of appropriate frequency by means interposed 22 via, for example, frequency shift keying, and can be demodulatingly detected accordingly by means interposed 25, both as shown in FIG. 2.

In a typically contemplated configuration, for example, the data stream respectively transmttted and received from one station to the next might include a typical preamble, an 8-bit network identifier to avoid interference with adjacent networks plus 2 parity bits, a 4-bit source transceiver identifier and a 4-bit target transceiver identifier plus 2 parity bits, an 8-bit command when indicated plus 2 parity bits, and, when indicated, one or two 8-bit information groups each with 2 parity bits. Naturally, when 4-bit source and target identifier logic is employed, the number of stations in a network is limited to a maximum of 16.

Referring to FIG. 3, which shows for the sake of simplicity in describing the operations thereof a local area network of the invention of only four transceiver stations, serially linked in a loop, such transceivers are numbered 31, 32, 33 and 34. Transceiver 34 has been

selected to operate as the network local control station. Connections between the respective transceivers and the systems of interest in each home are not shown.

When pertinent information, such as an alarm condition, for example, is modulatingly conveyed from the home system associated with transceiver station 32 to the transmitter thereof, that transceiver's programmed control means will direct such transmitter to address the transmission of such information to the receiver of transceiver station 33, and to transmit same. Upon receipt of such information at the station 33 receiver, the programmed control means of transceiver station 33 will, in turn, direct the transmitter thereof to address the transmission of the information concerning station 32, such as, for example, that there was an alarm, on to transceiver station 34, and to transmit same.

Optionally, each transceiver station will also include an indicator, which under alarm circumstances at station 32, for example, will announce appropriately at stations 33 and 34 that there is an alarm at station 32. Also, optionally, the programmed control means at station 32 can be made to cause the transmitter at 32 to repeatedly readdress the information concerning station 32 to transceiver station 33, and to re-transmit same a preset number of times in the interests of reliability, whereupon station 33 will likewise pass on the information concerning station 32 to station 34. Of course, each such transmission is of the form of the aforementioned data stream, and is, thus, effectively a short burst of a second or less in duration, depending upon, for example, the frequency shift keying rate.

As aforesaid, transceiver station 34 acts as local control station for the network. When the information regarding station 32, such as an alarm condition, reaches the receiver at station 34, a number of things can happen, depending on the instructions placed in the programmed controller at station 34. Typically, the information concerning station 32 will first of all be retrievably stored for future use. Next, station 34 will then generate a terminate command directed to station 32, and instructing that station to stop transmitting, and via said programmed control means, instruct the transmitter at station 34 to address a transmission of such command to station 31, and transmit same. The programmed control means at station 31 will in turn cause the transmitter there to address a transmission of such command to station 32, and transmit same. Upon receipt of the command by the receiver at station 32, transmissions of that particular information concerning station 32 will cease. However, if the alarm condition at station 32 persists and has not been locally reset, station 32 will retransmit after a predetermined period of time, whereupon it will in turn receive from station 34 via station 31 another terminate command. This cycle can be repeated a predetermined number of times. Likewise, station 34 can be programmed to send a terminate command only after each set of a predetermined number of repeated transmissions from station 32.

At station 32, as at each other station, there can be a first programmed time delay between the occurrence of an alarm condition and transmission of an alarm signal. This delay is to permit the homeowner to reset locally in the case of a false alarm. Optionally, at local oontrol station 34, there can also be placed in the programmed controller there a second predetermined time delay, such that if at station 34, a preselected number of repeated transmissions of the alarm information from station 32 are not received within the set time, then it will be recognized that there is no need to generate and transmit a termination command addressed to station 32. The usual circumstances in this respect will be a false alarm at station 32, recognized on the premises by the homeowner, who resets the system locally, but after expiration of the programmed time delay at station 32 first.

When the local area network shown in FIG. 3 is operating as a utility service network, the operation of the individual transceiver stations will not differ significantly from that described above insofar as passing usage data and specifically addressed commands about the serially linked loop is concerned. There may, however, have to be more data storage capability and more command generation capability in the programmed control means at the local control station 34 than would typically be the case when the network operates as a security network. This is simply because of greater detail required in utility service networks. For example, such control means would periodically generate and cause to be transmitted a command to station 32 to determine the amount of electric power usage at the individual home system there. After such command had been passed about the loop to station 32, station 32 would obtain from the associated system the reading 2344 kilowatt-hours, for example, and the programmed control means there at station 32 would cause that information to be likewise passed about the loop to local control station 34, where it would be retrievably stored.

In similar fashion, for load control situations where special utility rates are involved, the programmed control means at station 34 can, for example, at certain times of the day generate commands addressed to station 32 to respectively turn off and turn on the central air conditioner located there, and cause them to be passed about the loop to station 32, where such commands would be fed to the individual home system there. Preferably, the system at that home would then provide station 32 with a confirmation signal which the programmed control means at station 32 would cause to be passed about the loop to station 34. Receipt at station 34 of such a confirmation signal can be used to prevent further re-transmission of such appliance enabling or disenabling commands by station 34 to station 32.

The local area network of the invention preferably also includes verification means for periodically assessing the integrity of the network by assessing the operability of each transceiver therein. Verification operations can be understood by again referring to the simplified network shown in FIG. 3. At regular periodic intervals, the programmed control means at local control station 34 will generate a status command and cause the transmitter there to address such command to station 31 and transmit same. Upon receipt at station 31, the programmed control means there will cause the transmitter there to re-address the status command to station 32, and transmit same. In like fashion, if all transceivers are operative, the status command will be passed about the loop back to local control station 34, where it can be repeated, or not, depending upon the level of reliability desired.

However, suppose, for example, that transceiver station 32 is nonoperative, such that it fails to transmit to station 33 the status command which station 31 has addressed and transmitted to station 32. The receiver at station 31 will, of course, receive anything that station 32 transmits, whether addressed to station 31 or to station 33. Thus, instructions must be placed in the pro-

grammed control means at station 31 to recognize under status command circumstances when station 32 does transmit the command to station 33, and station 31's receiver also receives same, in which case station 31 need do nothing. Similarly, station 31 must be instructed to recognize when, during a predetermined period of time after its own transmitter sends the status command to station 32, station 31's receiver does not receive the transmission whereby station 32 sends the status command on to station 33.

In that case, station 31's programmed control means must generate a fault signal identified to station 32 and cause its transmitter to address such fault signal to station 34 and transmit same. Alternatively, station 31's programmed control means could instruct its transmitter to repeat the status command transmission to station 32, and then, only upon a double failure of station 32 to send the status command on to station 33, proceed to generate the fault signal and send it back to station 34. Naturally, the control means at each station in the network must be similarly programmed.

At transceiver station 34, the local control station, the programmed control means will, upon receipt from station 31 of the fault signal concerning station 32 preferably cause the station 34 transmitter to re-direct the status command the opposite way about the serially linked loop, addressing its transmission to station 33. Station 33, if operative, will attempt to transmit to station 32. Thereupon, if 32 remains inoperative, and fails to transmit to station 31, station 33 will recognize such failure and generate a fault signal, and send it back to station 34. Upon rceeipt of such fault signal, thus verified, station 34 will cause same to be retrievably stored, and will also cause same to be displayed. The purpose, of course, of transmitting the status command in both directions is not only to verify that station 32 is nonoperative. It is also to determine whether station 33 is operative or not. Also, optionally, each transceiver can display the status of each other transceiver.

Referring now to FIG. 4, a simplified network is also shown, similar to that in FIG. 3. Transceiver stations 41, 42, 43, and 44 are serially linked in a loop, with station 44 being the local control stations. Taken as such, this network operates just as does the network shown in FIG. 3. However, here two optional added features are also shown.

First, local control station 44 is shown linked with a remote control station. This link would typically be provided by a two-way, long-distance radio, normally of a type requiring an FCC license due to power and range, and the expense of which is shared by all homes in the network. Such remote control station could be located at a fire station, police station, private security headquarters, or offices of a public utility, for example. The purpose relates to both data storage and command generation, both of which can be done at the remote control station and passed on to the local control station for subsequent passage about the loop. The advantages are several. The local control station programmed control means need not be so elaborate, for one, and the data involved can be acted upon with more efficiency, whether it be connected with an alarm condition or with utility usage.

Next, connected with transceiver stations 41 through 44 are, respectively, modems 45 through 48. Each modem is, in turn, connected with the phone line, not shown, available at the home where the respective transceiver station is located. This is a solution intermediate the stand-alone local controller and the radio link to a remote control station.

Commands would still be generated at the local cnntrol station. However, information as to, for examlle, alarm conditions or utility usage, would be passed over the phone lines to a remote station elsewhere—in short, a one-way link. Information on conditions in the system associated with station 42, for example, whether it be an alarm condition or utility linkage, can be passed on for retrievable storage and action via modem 46 at the same location. If that phone line is inoperative or unavailable, the information can be passed about the loop to the first station where a phone line is both operative and available, and sent to the remote station via the modem at that station.

For example, a fire at station 42 can result in alarm condition information being sent out by phone via modem 46, as well as being passed about the loop to the local control station. But if the phone line at station 42 is down, modem 47 and the phone line at station 43 may be pressed into service to send out information on the alarm condition. The advantages, again, are several. Efficiency of data storage and action is achieved without the expense and trouble of a licensed transceiver. However, the slow transmission, possible disruption, and other potential problems with phones must be accepted. Command generation at the local control station also requires a more elaborate controller than is the case with the two-way, long-distance radio link to the remote control station.

Turning now to FIG. 5, the preferred form of circuitry for a typical transceiver station is shown in block diagram form. In addition to the transceiver proper, indicated generally at 101, the station includes as major components a microprocessor unit (MPU) 102, an EPROM 103, and an E^2PROM 103A, interconnected via Decoder 103B. One advantage of E^2PROM 1O3A, of course, is that it does not have to be removed to be re-programmed.

The EPROM 103, when properly programmed, contains in its memory all of the instructions required for proper operation of the transceiver station. Included at specifically identifiable addresses are, for example, instructions concerning status commands and instructions concerning terminate commands. Likewise E^2PROM 1O3A, when properly programmed, contains at specific addresses in its memory identification information unique to the network, identification information unique to this particular transceiver, identification information unique to the next proximate downstream transceiver station, and identification information unique to the next proximate upstream transceiver station. A RAM may be substituted for E^2PROM 103A, but if so, will require a backup battery to prevent memory loss associated with power outages and the like.

The MPU 102 monitors the status of power supply 1O4, and also addressably monitors the status of, for example, eight inputs from the security or other system in the home wherein the transceiver station is located via 8-bit latch 105. Further, MPU 102 serves to generate in connection with EPROM 103 commands which it addressably delivers to, for example, eight outputs to said security or other system via 8-bit latch 106. Further still, MPU 102 serves to decode bit streams delivered by the receiver portion of the transceiver proper and serves to encode and deliver bit streams to the transmitter portion of the transceiver proper, all in conjunction with instructions and information programmed into

EPROM 103 and E^{2}PROM 1O3A, respectively. Additionally, MPU 1O2 also is addressably interconnected with a display unit 107, and with a manually operated switch PB, such as a push button, which can be assigned to a function such as, for example, disenabling alarm transmissions under false alarm circumstances.

The transceiver proper, indicated generally at IOI, is, as aforesaid, adapted to operate at frequency and power levels not requiring an FCC license for transmission purposes, and should preferably by designed for maximum sensitivity and range within the applicable FCC restrictions, while still being moderate in cost. It must also meet FCC spurious emission standards when transmitting, while rejecting spurious and unwanted signals when receiving, in order to achieve the desired system reliability and security.

As shown, the transceiver utilizes a single antenna ANT for both reception and transmission, although it will be readily recognized that separate antennas may be utilized, especially when optionally utilizing a split-frequency mode of operation. Here, antenna operation within the circuit is controlled by Transmit-Receive (T/R) Swttch 108, which is in turn controlled by MPU 102. A usual with such switches, as generally known in the art, T/R Switch 108 is in normal operation in receive mode at aall times except when actually carrying out a transmission instruction.

The receiver portion of the transceiver proper is shown as a double conversion receiver. The frequency modulated signal captured by the antenna is directed via the switch I08 through band-pass filter 109, through low-noise amplifier 110, through second band-pass filter 111, to first mixer 112. Mixer 112 converts the signal from one centered about the carrier as captured by antenna ANT to one centered about a lower frequency determined by frequency synthesizer 113 in conjunction with MPU 102, such as, for example, 10.7 MHz.

The signal next proceeds through band-pass filter 114, which limits the bandwidth to, for example, 15 KHz, and thence through amplifier 115 to second mixer 116. Second mixer 116, in conjunction with crystal oscillator 117 converts the signal from one centered about the first intermediate frequency carrier to one centered about a second lower intermediate frequency carrier, such as, for example, 455 KHz.

Next, the signal is demodulated by demodulator 118, via a quadrature detector. The informational signal thus obtained is next passed through limiting amplifier 119 for signal enhancement, whence it is delivered to MPU 102. Demodulator 118 also delivers a dc output proportional to receiver signal strength, which is in essence a carrier detection indicator. The level of this output is compared to a predetermined dc level by comparator 120, and the result is also delivered to MPU 102.

If the output from comparator 120 is sufficient to indicate the presence of a carrier, MPU 102 will examine the informational signal delivered by limiting amplifier 119. First, MPU 102 will determine whether such signal is a bit stream of the proper format for the network. If not, the MPU will return to standby status, essentially a monitoring function. But if so, then MPU 102 looks for a start bit and attempts to decode the first word, typically the network identifier, by comparing same with predetermined information stored in E^{2}PROM 103A. If such word is not correct for the system, MPU 102 returns to standby status. But if the network identifier is correct, then MPU 102 proceeds to likewise attempt to decode the second word, which typically includes the signal-originating source transceiver identifier.

In similar fashion, MPU I02 proceeds seriatim through the bit stream, going next to the transmission-source-transceiver identifier, the target transceiver identifier, the command word or words, the informational word or words, and so forth. In each instance, MPU 102 compares the word with predetermined words stored in E^{2}PROM 103A. In each instance, a proper match permits progress to the next word, while an improper match returns the MPU to standby status. Notably, in each instance where MPU 102 returns to standby status it will where the signal delivered by comparator 120 still indicates the presence of a carrier, re-attempt to decode the informational signal delivered by limiting amplifier 119.

In decoding a bit sream of proper format delivered by limiting amplifier 119, MPU 102 calculates parity for each word and compares the result with the parity bit or bits included following the word to determine whether the word is error free. If so, the word is internally stored without the parity bits. If not, the decoding attempt is aborted and the MPU returns to standby status. As aforesaid, MPU 102 will re-attempt decoding if a carrier is still present, but will otherwise merely continue monitoring functions, such as with respect to those inputs associated with the home security system, for example.

Turning now to the transmitter portion of the transceiver, the transmission of a bit stream is required upon any of several occasions. For example, a received bit stream may be one that must be re-transmitted to the next transceiver station downstream in the loop. For further example, a received bit stream may contain a commadd requiring the transmission of data concerning the system in the home where the transceiver is located. For still further example, if the home system in question is a security system in alarm condition, then information on that condition must be transmitted, and thus sent on its way around the loop.

In each instance, the appropriate information and commands, together with the target and source identifiers are obtained from EPROM 103 and E^{2}PROM 103A by MPU I02. MPU I02, via an encoder routine also called up from the EPROM 103, appropriately Manchester-phase-encodes all such information into a signal in the form of a bit stream. This signal must be appropriately processed to limit the bandwidth of the eventually resulting modulated carrier. Consequently, MPU 102 delivers the signal to fm deviation control 121, which limits the frequency deviation to 2 to 3 KHz, for example. The signal proceeds, in turn, through band pass filter 122 which diminishes harmonic content in order for the eventually resulting modulated carrier to comply with FCC regulations.

Frequency synthesizer 113 generates a carrier at a frequency determined by MPU 102, and delivers such carrier to modulator portion 123, to which is also delivered the bit stream from band pass filter 122. Modulator 123 proceeds to suitably modulate the carrier with the bit stream, via, for example, a voltage-controlled reactance, such as a varactor diode, whihh permits the modulating signal to shift the oscillator frequency proportional to signal amplitude. The resulting modulated carrier is amplified by amplifiers 124 and 125, and thereafter filtered by band pass filter 126 to suppress spurious signals and harmonics.

Next, the modulated carrier is delivered, via T/R switch 108 and low pass filter 127 to antenna 107. T/R switch 108, has, of course, been switched by MPU 102 from receive mode to transmit mode. Low pass filter 127 acts to further diminish harmonics to an acceptable level in accordance with FCC requirements.

When a transceiver station such as that shown in FIG. 5 is selected to be the one station acting as local control station for the network, no additional or different hardware is needed. Said otherwise, the components and interconnections shown by FIG. 5 remain the same. EPROM 103 will contain additional commands, such as those associated with generating signals for assessing the integrity of the network, as well as a sub-routine which, working in conjunction with an internal clock in MPU 102, will periodically cause appropriate transmission of such commands. Likewise, MPU 102 will have an internal RAM with sufficient capacity to store information received by th local control station from the various transceiver stations in the loop. Naturally, additional storage capacity can be added, if need be, via one or more additional E^2PROM units, not shown, or, alternatively, battery-backed RAM units.

FIG. 6A shows in block diagram form a typical interconnection between a transceiver station such as shown in FIG. 5 and the telephone line associated with the home where the transceiver station is located, an optional feature. Such station may be the local control station, but need not be, frr the interconnection is the same. Transceiver station 201 contains all of the circuitry shown in FIG. 5 with the outputs, inputs, display, power source, and antenna shown in FIG. 6A all connected as indicated in FIG. 5. A data bus from transceiver station 201 is interconnected with the telephone line via modem 202, and 8-bit latches 203 and 204. Address logic unit 205 is provided to act in conjunction with commands delivered by MPU 102 from EPROM 103, neither of which is shown here, to enable the required information, such as an alarm condition, for example, to be sent via phone toaa predetermined phone number, such as that of the local fire station, for example. It will be recognized that the arrangemen shown in FIG. 6A is in general like that usually utilized, in that it can also receive information by phone line, as well as send out information. While the operation contemplated in connection with the present locll area network is concerned entirely with sending out information, the possibility of receipt by any transceiver station of nnstructions or information via phone line is to be understood as being part of this invention.

FIG. 6B shows a transceiver station as in FIG. 5 which has been selected to operate as local control station, and which is, optionally, provided with both a telephone line interconnection as in FIG. 6A, and, optionally also provided with the capability of two-way communication with a central station via a long-range licensed transceiver. Transceiver station 301 is interconnected with the phone line via modem 302, 8-bit latches 303 and 304 and address logic unit 305, just as shown in FIG. 6A. Long-range transceiver 306 is connected to previously unused I/O lines of latches 303 and 304 which interface it to the data bus from transceiver 301. Typically, a portion of each of the lines in latches 303 and 304 are dedicated respectively to the modem and the transceiver. An additional carrier detection interconnection is placed directly between long-range transceiver 306 and transceiver station 301, as shown. Long-range transceiver 306 is provided with an additional antenna 307, appropriate to its particular operating frequencies, different from those of transceiver station 301.

FIG. 7 shows in block diagram form a transceiver station such as shown in FIG. 5 typically interconnected with the utility distribution system of the home where such station is located. The components and connections within transceiver station 401 are as shown in FIG. 5, and the interconnections therewithin to the power source, display, antenna, and sets of inputs and outputs are likewise as shown in FIG. 5. Here, external connections are shown between the transceiver station inputs and, for example, kilowatt hour meters 402 and 403, another meter 404 which may be a gas meter, for example, and the level detector of a water tank 405 for example. Similarly, external connections are shown between the outputs of transceiver station 401 and pump 40B associated with tank 405, relay 406 which may be associated with an air conditioner, for example, and hot water heater relay 407.

Data as to utility usage accumulated by the meters is delivered to transceiver station 401 inputs and stored in an E^2PROM or RAM, not here shown, from whence it can be accessed by the utility company as explained heretofore. Naturally, additional memory capacity can be added within transceiver station 401, if need be. Likewise, commands either stored in EPROM 103 or received by the receiver portion of transçeiver 401, can be delivered via the outputs of transceiver station 401 to the various appliances involved. Such commands would typically serve to turn such appliances on or off.

It will be recognized that data as to utility usage can be derived by or at the meter in question by any of several ways heretofore known or proposed. For example, given a typical home-type kilowatt hour meter wherein a motor spins a disc at a rate proportional to power usage, one can via reflected light generate a pulse per revolution by recognizing each time the black spot on the disc travels by a preselected location. Likewise, one could also put a hole in the disc and generate via transmitted light a pulse per revolution each time the hole travels by a preselected location. The light generating and detecting means by which such hole or such spot can generate an electrical pulse are well known. Similar arrangements can readily be contemplated in respect of, for example, a gas meter wherein the revolution of a small turbine is proportional to volumetric flow.

Yet another available option for use in connection with the local area network of the invention involves the use of multiple frequencies or radio channels, to avoid problems with interference, interception, or jamming, where exceptionally secure networks are required. The receiver portion of the transceiver can be arranged, using recognizably available technology, to scan for transmissions or, for example, eight preselected frequencies within an available band, uuch as, for example, 300–320 MHz. Likewise, referring again to FIG. 5, the MPU 102 can direct the frequency synthesizer 113 to supply transmission carrier on any of a group of the preselected frequencies within the band which the receivers in the loop are scanning. In conjunction with instructions placed in EPROM 103, MPU 102 can direct that each transmission be on a different frequency. Indeed, the group of preselected frequencies can be changed from time to time, to another group within the band, upon instructions from the local control station.

Still a further option within the contemplation of the invention involves the elimination of both licensed,

two-way long distance transceivers and phone lines under circumstances where multiple networks are located in proximity to each other, wiile still providing means for communications between each network and a central station. This can be accomplished by serially linking each of the local area network control stations in a loop of control stations, one of which is at a central station. Information and instructions would be passed about this loop from control station to control station in precisely the same manner as from station to station in any local area network. Each local control station would need multiple channel capability, with particular channels dedicated to use only in the loop of control stations. Likewise, an identifier would need to be assigned to each control station, based on the network identifier already established. Naturally, the transceiver at the central station would require additional storage capacity and additional instruction generating programming, and would thus be expected to contain a plurality of E^2PROM units, or, alternatively, RAM units with battery back-up.

While the present invention has been described in connection with illustrated embodiments, it will be appreciated and understood that modifications may be made without departing from the true spirit and scope of the invention.

That which is claimed is:

1. A local area network for digital information transmission to and from each of a plurality of building units in an area, wherein all network interconnections between any of said plurality of units and any other of said plurality of units are wireless and employ no cables, said network comprising a plurality of transceiver stations, one each being located at each of said plurality of units, each said transceiver station including:

radio transmitter means adapted to transmit information in digital form, and further adapted to selectively address said transmitted information to at least either of two proximately located other transceiver stations of said plurality, said transmitter means being operable in a frequency range and at a sufficiently low maximum power level as to be normally and lawfully utilizable without an FCC license;

radio receiver means adapted to receive transmissions of information in digital form, and further adapted to specifically recognize such transmissions selectively addressed to said receiver means from at least either two proximately located other transceiver stations of said plurality;

interface means interconnecting said transceiver means with at least one electrical system associated with said unit of said plurality where said transceiver station is located and adapted to accept data from said system and deliver commands to said system;

first means interposed between said interface means and said radio transmitter means and adapted to modulatingly convey said data from said interface means to said radio transmitter means; and

second means interposed between said first interface means and said radio receiver means and adapted to demodulatingly convey said commands from said radio receiver means to said interface means;

programmable control means adapted to cause said transmitter means to recognizably and selectively retransmit data and commands received by said receiver means in a predeterminable manner;

whereby said plurality of transceiver stations may be serially linked in a loop; and

further whereby commands for any of said systems and data from any of said systems may be passed from station to station about the loop in either of two directions.

2. A local area network as in claim 1, wherein a predetermined one of said plurality of transceiver stations is selected to act as a local control station for the network, said predetermined transceiver station further including means for generating commands addressed to any of the other transceiver stations of said plurality and means for retrievably storing data recognizably received from any of the other transceiver stations of said plurality.

3. A local area network as in claim 1, further comprising means interconnecting a remote control station with any of said transceiver stations of said plurality and adapted to transmit to said remote control station data from any of said plurality of transceiver stations and further adapted to receive from said remote control station commands addressed to any of said plurality of transceiver stations.

4. A local area network as in either of claims 2 or 3 further comprising verification means for periodically assessing the integrity of the network by ascertaining the operability of each transceiver station therein, said verifccation means including means for generating a status command addressed to a first transceiver station among the serially linked plurality of stations in the loop, means within said first station and within each other transceiver station in the network for directing said radio transmitter means therein to address said status command to the next downstream transceiver station in the loop and re-transmit said command thereto, means within said first transceiver station and within each other transceiver station for recognizing when said next downstream station fails to re-transmit said status command, means within said first transceive station and within each other transceiver station for generating a fault signal upon recognizing the failure of said next downstream station to re-transmit said status command, means within said each other transceiver station for directing said radio transmitter means therein to address said fault signal to the next upstream transceiver station in the loop and to transmit said signal thereto, and means within said first transceiver station for directing said fault signal back to said means for generating a status command, and means within said generating means for recognizing, storing, and acting upon said fault signal.

5. A local area network as in claim 4 wherein said means for generating a status command is located within said local control station, and said first transceiver station is said local control station.

6. A local area network as in claim 4 wherein said means for generating a status command is located within said remote central station, and said first transceiver station is said any of said transceiver stations associated with said remote central station via said means interconnecting.

7. A local area security network for wirelessly interconnecting the individual security systems of a plurality of homes in a neighborhood and for transmission in digital form to and from each said home information concerning security system alarm conditions and other information, and network comprising a plurality of transceiver stations, one each being located at each of

said plurality of homes, each said transceiver station including:

radio transmitter means adapted to transmit information in digital form, and further adapted to selectively address said transmitted information to at least either of two proximately located other transceiver stations of said plurality, said transmitter means being operable in a frequency range and at a sufficiently low maximum power level as to be normally and lawfully utilizable without an FCC license;

radio receiver means adapted to receive transmissions of information in digital form, and further adapted to specifically recognize such transmissions selectively addressed to said receiver means from at least either of two proximately located other transceiver stations of said plurality;

interface means interconnecting said transceiver means with the individual home security system associated with said home of said plurality where said transceiver station is located and adapted to recognizably accept information concerning alarm conditions from said system and deliver alarm termination commands to said system;

first means interposed between said interface means and said radio transmitter means and adapted to modulatingly convey said alarm condition information from said interface means to said radio transmitter means;

second means interposed between said interface means and said radio receiver means and adapted to demodulatingly convey said alarm termination commands from said receiver means to said interface means;

programmable control means adapted to cause said transmitter means to recognizably and selectively retransmit said alarm condition information and said alarm termination commands received by said receiver means in a predeterminable manner; and

indicator means adapted to recognizably and selectively indicate the existence of an alarm condition in the security system of any other home of said plurality;

whereby said plurality of transceiver stations may be serially linked in a loop; and

whereby alarm condition information and alarm termination commands may be passed from station to station about the loop in either of two directions; and

further whereby an alarm condition in any security system of said plurality of homes can be selectively and recognizably indicated in at least one other of said plurality of homes.

8. A local area security network as in claim 7, wherein a predetermined one of said plurality of transceiver stations is selected to act as a local control station for the security network, said predetermined transceiver station further including means for generating alarm termination commands addressed to any of the other transceiver stations of said plurality and means for retrievably storing information concerning alarm conditions recognizably received from any of the other transceiver stations of said plurality.

9. A local area security network as in claim 7, further comprising means interconnecting a remote control station with any of said transceiver stations of said plurality and adapted to transmit to said remote control station information concerning said alarm conditions from any of said plurality of transceiver stations and further adapted to receive from said remote control station alarm termination commands addressed to any of said plurality of transceiver stations.

10. A local area security network as in either of claims 8 or 9 furthrr comprising verification means for periodically assessing the integrity of the network by ascertaining the operability of each transceiver station therein, said verification means including means for generating a status command addressed to a first transceiver station among the serially linked plurality of stations in the loop, means within said first station and within each other transceiver station in the network for directing said radio transmitter means therein to address said status command to the next downstream transceiver station in the loop and re-transmit said command thereto, means within said first transceiver station and within each other transceiver station for recognizing when said next downstream station fails to re-transmit said status command, means within said first transceiver station and within each other transceiver station for generating a fault signal upon recognizing the failure of said next downstream station to re-transmit said status command, means within said each other transceiver station for directing said radio transmitter means therein to address said fault signal to the next upstream transceiver station in the loop and to transmit said signal thereto, and means within said first transceiver station for directing said fault signal back to said means for generating a status command, and means within said generating means for recognizing, storing, and acting upon said fault signal.

11. A local area security network as in claim 10 wherein said means for generating a status command is located within said local control station, and said first transceiver station is said local control station.

12. A lccal area security network as in claim 10 wherein said means for generating a status command is located within said remote control station via said means interconnecting.

13. A local area utility service network for wirelessly interconnecting the individual utility distribution systems of a plurality of homes in a neighborhood and for transmission in digital form to and from each said home information concerning utility usage and other information, said network comprising a plurality of transceiver stations, one each being located at each of said plurality of homes, each said transceiver station including:

ratio transmitter means adapted to transmit information in digital form, and further adapted to selectively address said transmitted information to at least either of two proximately located other transceiver stations of said plurality, said transmitter means being operable in a frequency range and at a sufficiently low maximum power level as to be normally and lawfully utilizable without an FCC license;

radio receiver means adapted to receive transmissions of information in digital form, and further adapted to specifically recognize such transmissions selectively addressed to said receiver means from at least either of two proximately located other transceiver stations of said plurality;

interface means nnterconnecting said transceiver means with at least one utility distribution system associated with said home of said plurality where said transceiver station is located and adapted to recognizably accept information concerning utility

usage from said system and deliver appliance enabling and disenabling commands to said system;

first means interposed between said interface means and said radio transmitter means and adapted to modulatingly convey said utility usage information from said interface means to said transmitter means;

second means interposed between said interface means and said radio receiver means and adapted to demodulatingly convey said appliance enabling and disenabling commands from said receiver means to said interface means; and

programmable control means adapted to cause said transmitter means to recognizable and selectively retransmit said utility usage information and said appliance enabling and disenabling commands received by said receiver means in a predetermined manner;

whereby said plurality of transceiver stations may be serially linked in a loop; and

whereby utility usage information and appliance enabling and disenabling commands may be passed from station to station about the loop in either of two directions.

14. A local area utility service network as in claim 13, wherein a predetermined one of said plurality of transceiver stations is selected to act as a local control station for the network, said predetermined transceiver station further including means for generating appliance enabling and disenabling commands addressed to any of the other transceiver stations of said plurality and means for retrievably storing information regarding utility usage recognizably received from any of the other transceiver stations of said plurality.

15. A local area network as in claim 13, further comprising means interconnecting a remote control station with any of said transceiver stations of said plurality and adapted to transmit to said remote control station information regarding utility usage from any of said plurality of transceiver stations and further adapted to receive from said remote control station commands addressed to any of said plurality of transceiver stations.

16. A local area network as in either of claims 14 or 15 further comprising verification means for periodically assessing the integrity of the utility service network by ascertaining the operability of each transceiver station therein, said verification means including means for generating a status command addressed to a frrst transceiver station among the serially linked plurality of stations in the loop, means within said first station and within each other transceiver station in the network for directing said radio transmitter means therein to address said status command to the next downstream transceiver station in the loop and re-transmit said command thereto, means within said first transceiver station and within each other transceiver station for recognizing when said next downstream station fails to re-transmit said status command, means within said first transceiver station and within each other transceiver station for generating a fault signal upon recognizing the failure of said next downstream station to re-transmit said status command, means within said each other transceiver station for directing said radio transmitter means therein to address said fault signal to the next upstream transceiver station in the loop and to transmit said signal thereto, and means within said first transceiver station for directing said fault signal back to said means for generating a status command, and means within said generating means for recognizing, storing, and acting upon said fault signal.

17. A local area security network as in claim 16 wherein said means for generating a status command is located within said local control station, and said first transceiver station is said local control station.

18. A local area security network as in claim 16 wherein said means for generating a status command is located within said remote control station via said means interconnecting.

19. A local area network as in any of claims 3, 9 or 15, wherein said means interconnecting a remote control station with any of said transceiver stations of said plurality of further comprises a higher power, licensed, two-way radio transceiver of a predetermined frequency range and mode of modulation operatively associated with said any of said transceiver stations of said plurality.

20. A local area network as in any of claims 3, 9 or 15, wherein said means interconnecting a remote control station with any of said transceiver stations of said plurality further comprises a modem interconnected between said any of said transceiver stations of said plurality of and a telephone line associated with the building unit at which said any of said transceiver stations is located.

21. A local area network as in any of claims 3, 9 or 15, wherein said means interconnecting a remote control station with said any of said transceiver stations of said plurality of further comprises a plurality of modems, one each interconnected between each said transceiver station of said plurality of and the telephone line associated with the building unit where said transceiver station is located, and wherein said programmable control means included within said any of said transceiver stations is further adapted to transmittably and selectively command the utilization of any of said plurality of modems as said means interconnecting.

22. A local area network as in any of claims 1, 7 or 13, wherein said receiver means further comprises means for scanning a preselected set of frequencies, said transmitter means further comprises means for transmitting on any of said set of preselected frequencies, and said programmable control means is further adapted to determine the one frequency of said preselected set of frequencies at which said transmitter means may transmit at any given point in time.

23. A local area network as in any of claims 2, 8 or 14, wherein said transceiver station selected to act as a local control station further comprises second transmitter means and second receiver means adapted to transmit and receive signals of at least one second frequency other than that utilized by said network, and further programmable control means adapted to cause said second transmitter means and said second receiver means to respectively transmit, receive and retransmit data and commands at said second frequency, whereby the local control stations of a plurality of adjacent locl area networks may be serially linked in a loop.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 4,792,946 Page 1 of 2

DATED : December 20, 1988

INVENTOR(S) : Scott T. Mayo

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Abstract, line 5, "and" should be -- an --.
Column 1, line 56, "arge" should be -- large --.
Column 2, line 47, "proximitely" should be -- proximately --;
line 66, "recognizally" should be -- recognizably --.
Column 5, line 33, "menns" should be -- means --;
line 34, before "typical" insert -- a --.
Column 6, line 26, "beteeen" should be -- between --;
line 53, "transmttted" should be -- transmitted --.
Column 7, line 63, "oontrol" should be -- control --.
Column 8, line 19, "utllity" should be -- utility --.
Column 9, line 43, "stations" should be -- station --.
Column 10, line 4, "cnntrol" should be -- control --;
line 5, "amlle" should be -- ample --.
Column 11, line 2, "1O2" should be -- 102 --;
line 7, "IOI" should be -- 101 --;
line 23, "Swttch" should be -- Switch --;
line 24, "A" should be -- As --;
line 26, "aall" should be -- all --;
line 31, "I08" should be -- 108 --.
Column 12, line 3, "I02" should be -- 102 --.
line 36, "commadd" should be -- command --;
line 45, "I02" (both occurrences) should be -- 102 --;
line 63, "whihh" should be -- which --.
Column 13, line 16, "I02" should be -- 102 --;
line 29, "frr" should be -- for --;
line 40, "toaa" should be -- to a --;
line 46, "locll" should be -- local --;
line 49, "nnstructions" should be -- instructions --.
Column 14, line 56, "uuch" should be -- such --.
Column 15, line 3, "wiile" should be -- while --.

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 4,792,946

DATED : December 20, 1988

INVENTOR(S) : Scott T. Mayo

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 16, line 28, "verifccation" should be -- verification --;
line 39, "transceive" should be -- transceiver --;
line 67, "and" should be -- said --.
Column 18, line 37, "lccal" should be -- local --.
Column 19, line 14, "recognizable" should be -- recognizably --;
line 48, "frrst" should be -- first --.
Column 20, line 18, omit "of";
line 28, omit "of";
line 34, omit "of" (first occurrence);
line 36, omit "of" (second occurrence);
line 62, "locl" should be -- local --.

Signed and Sealed this

Twentieth Day of June, 1989

Attest:

DONALD J. QUIGG

Attesting Officer

Commissioner of Patents and Trademarks